6. ALTERNATIVE SCENARIOS

6.1 DEVELOPMENT OF ALTERNATIVE TUNNEL SCENARIOS

The preliminary West, Central and East main tunnel alignments were evaluated to determine the impacts that each may have on the groundwater system within the project area. Each of the tunnel alignments extend from near the Indiana State Fairgrounds on the north to the Interplant Connection Site on the south. The length of the tunnel alignments varies between approximately 8 to 10 miles. The three (3) preliminary tunnel alignments laid out in the groundwater model are shown on Figure 6.1. The alternative tunnel scenarios were developed for the project to evaluate short-term construction impacts and long-term operation and maintenance impacts to the surficial and deep bedrock aquifers. This fits together with the overall goal of the Groundwater Management Plan (GWMP) to protect and limit impacts to the groundwater resources in Indianapolis during construction and operation of the future bedrock tunnel.

Groundwater inflows during construction and long term operation are dependent upon the methodology and materials used to construct the tunnel. For this evaluation, it is assumed that the tunnel would be mined using a shielded hard rock tunnel boring machine capable of pre-excavation grouting; supported with rock bolts, wire mesh and occasional steel sets; and lined with cast-in-place concrete. Primary and secondary contact grouting would also be completed following liner placement to seal the tunnel from groundwater infiltration and exfiltration. For this evaluation, it is assumed that the cast-in-place concrete liner and contact grouting will occur following the excavation of the entire length of tunnel as a two-pass system. This is consistent with the Fall Creek/White River Tunnel Evaluation Study and Preliminary Design (Black & Veatch, 2005).

Table 6.1 presents the 12 alternative tunnel groundwater infiltration scenarios that were evaluated using the groundwater model. Each of the three (3) tunnel alignments were modeled using the following four (4) scenarios:

- Expected infiltration conditions during construction
- High infiltration during construction

6. ALTERNATIVE SCENARIOS

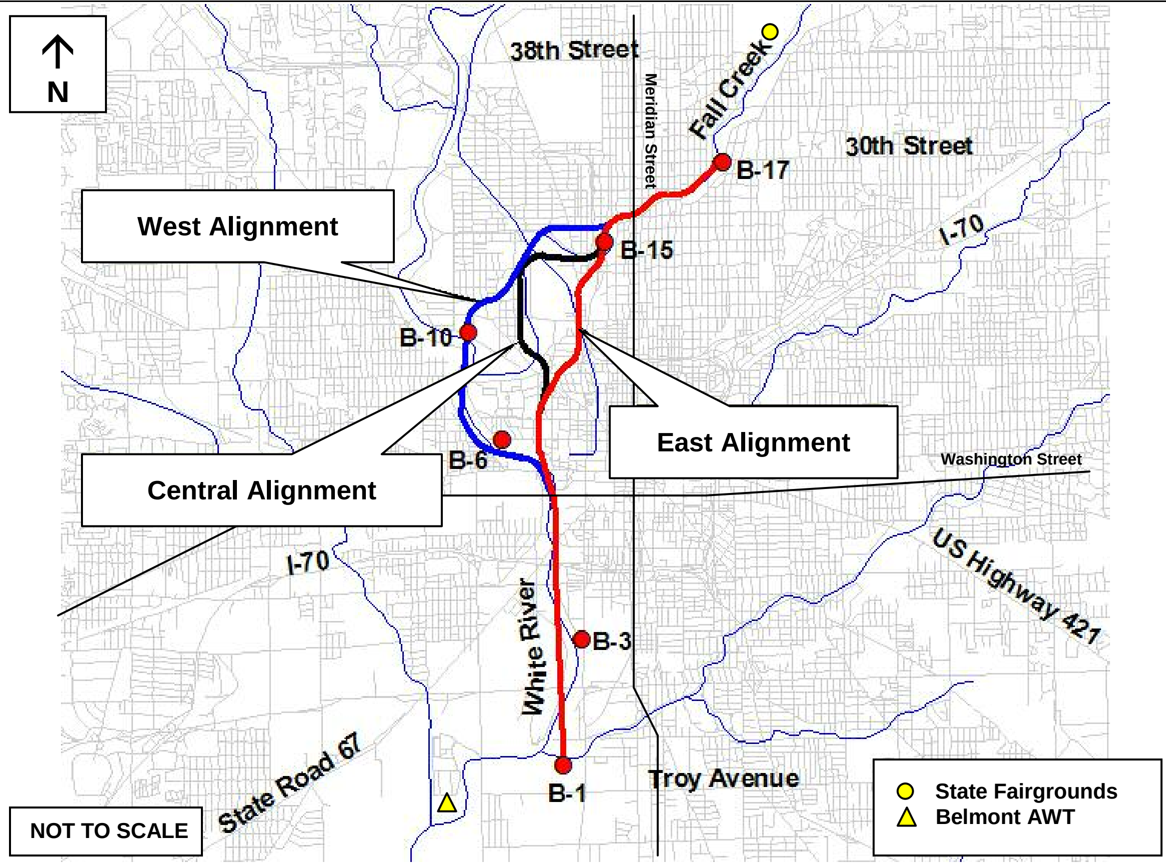

Figure 6.1 Tunnel Alignments
(all alignments extend from B-1 to B-17)

6. ALTERNATIVE SCENARIOS

- Expected infiltration conditions during long term operation
- High infiltration during long term operation

While it is not possible to predict exact water inflows into rock tunnels during construction, methods have been developed by the tunneling industry to predict possible groundwater inflows that could be experienced. The Fall Creek and White River Tunnel expected and high tunnel infiltration rates during construction were estimated using a semi-empirical method, known as the Heuer Method. This method relies upon the permeability testing data obtained from borehole water pressure testing results. Historical results, which allow for a comparison of predicted versus actual inflow rates from constructed tunnel projects, have shown actual inflow generally ranges from one-half (1/2) to two (2) times the estimated value.

Table 6.1
Alternative Tunnel Scenarios

Scenario	Condition
1	West alignment, expected infiltration rates during construction
2	Central alignment, expected infiltration rates during construction
3	East alignment, expected infiltration rates during construction
4	West alignment, high infiltration rates during construction
5	Central alignment, high infiltration rates during construction
6	East alignment, high infiltration rates during construction
7	West alignment, expected infiltration rates during operation
8	Central alignment, expected infiltration rates during operation
9	East alignment, expected infiltration rates during operation
10	West alignment, high infiltration rates during operation
11	Central alignment, high infiltration rates during operation
12	East alignment, high infiltration rates during operation

Based upon the Phase 1A geotechnical borings tested along the tunnel alignment, an estimated infiltration rate of 2,050 gallons per minute (gpm) for the entire tunnel was used for the expected infiltration conditions during construction. This inflow rate is two (2) times greater than the anticipated inflow rate predicted using the Heuer

Method. The inflow rate of 6,900 gpm for the entire tunnel was estimated for the high infiltration during construction. This high infiltration rate is approximately three (3) times greater than the predicted worst case conditions calculated using the Heuer Method.

The expected groundwater infiltration rate of 520 gpm for the entire tunnel during long term operation was established based upon the industry standard leakage criterion of 200 gallons per day per inch diameter per mile of tunnel. While the allowable infiltration rate during operations is anticipated to be negotiated with regulators in the future, this leakage criterion is typical in the industry and was used in Milwaukee's Northwest Side Relief Sewer Tunnel, and is more conservative than Chicago's TARP tunnels allowable leakage rate. However, it should be noted that the current Ten State Standards indicate 100 gallons per day per inch mile for sewers, which may be required. To establish the high infiltration rate during long term operations, the expected leakage rate was tripled to 600 gallons per day per inch diameter per mile of tunnel. This corresponds to a high infiltration rate during long term operations of 1,560 gpm. Table 6.2 summarizes the infiltration rates used in modeling the alternative scenarios.

Table 6.2
Infiltration Rates along Tunnel Alignment

Condition	Rate
Expected infiltration rate during construction	2,050 gpm
High infiltration rate during construction	6,900 gpm
Expected infiltration rate during operation	520 gpm
High infiltration rate during operation	1,560 gpm

6.2 MODEL DEVELOPMENT FOR ALTERNATIVE SCENARIOS

Groundwater models were developed for future conditions to predict the potential impact of the deep tunnel construction and operation on the groundwater aquifer beneath Indianapolis for the alternative scenarios. The tunnel was simulated using

6. ALTERNATIVE SCENARIOS

MODFLOW's "Drain Package", which allows the removal of groundwater from the system based on the head differential between the aquifer and the water level in the tunnel. A drain conductance parameter for the Drain Package controls the amount of flow leaving the aquifer into the tunnel. This parameter was varied until the infiltration rate given by the model matched the rate shown in Table 6.2 for each respective scenario. Models were created for each of the three (3) tunnel alignments, and the tunnel was simulated in Layer 4, approximately 2 to 3 tunnel diameters below the top of the carbonate rock. Figure 6.2 shows a typical cross section from north to south in the model along the tunnel alignment, including the elevation of the tunnel within the carbonate rock.

6.3 MODELING RESULTS

The model results for each of the alternative tunnel scenarios were compared to the existing conditions model results to estimate the potential impact to groundwater levels during tunnel construction and long-term operation. The potential impact is referred to as drawdown, which is defined as the difference between existing groundwater heads and future groundwater heads. Figures are provided later in this section showing the results of the drawdown that were calculated for selected scenarios. Because of the length of the tunnel, it is difficult to show drawdown in relation to the wells along the entire alignment, so the figures show the section of tunnel near the more critical Riverside and White River wellfields. The wells identified with "RS" are part of the Riverside Wellfield, and the wells identified with "WR" are part of the White River Wellfield. The results shown for this section of tunnel are representative of the results obtained along the entire tunnel length.

The model results indicate the tunnel causes greater drawdown in the deep carbonate aquifer than in the surficial aquifer because of the resistance to vertical groundwater movement through the aquifer layers. In addition, some of the drawdown in the upper aquifer layers is offset by induced recharge from the streams. These observations are discussed further for each of the scenarios. Available information indicates that most of the deep wells drilled into the carbonate aquifer draw the majority of their water from the shallow carbonate aquifer, and induce

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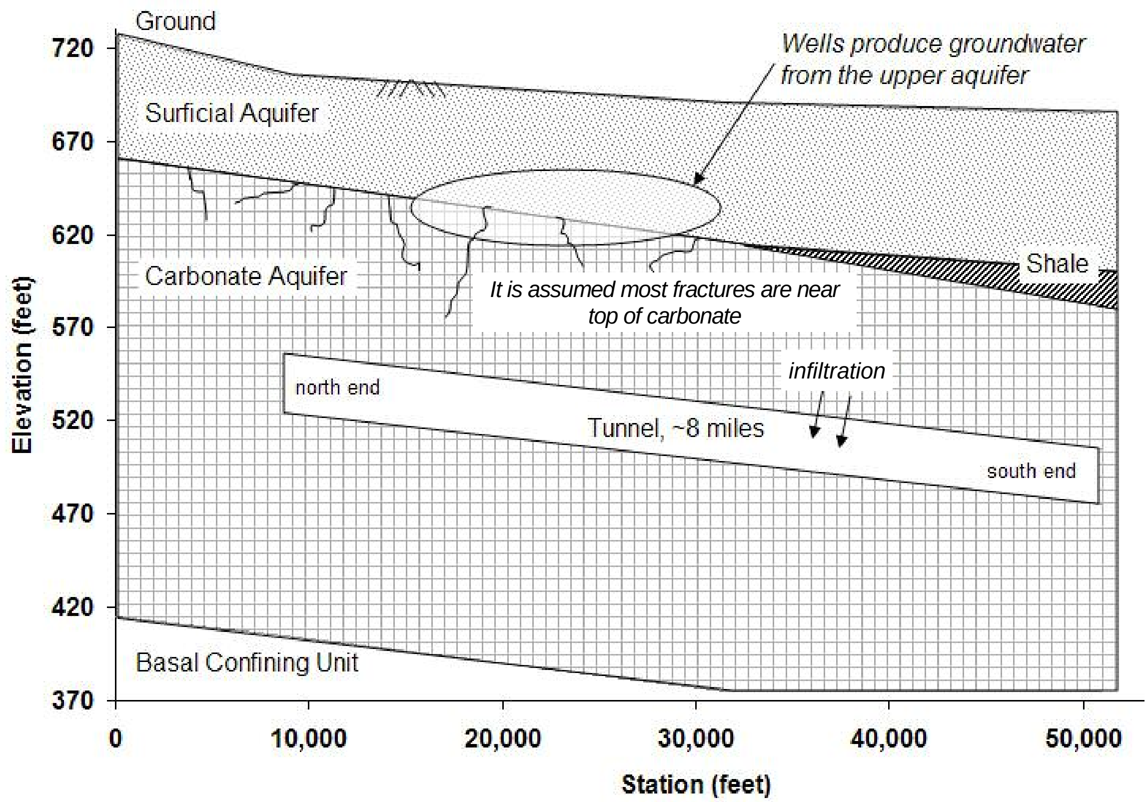

Figure 6.2 Cross Section along Tunnel Alignment

groundwater downward from the surficial aquifer. Based on the hydrogeologic discrete packer testing that was completed for the deep carbonate aquifer during the Phase 1A Geotechnical Program, it is evident that there is limited vertical and horizontal groundwater movement in the deep carbonate aquifer at the locations of the test borings.

The drawdown caused by the tunnel at each of the bedrock wells is determined from the results for the shallow carbonate represented by Layer 2 of the model where it is believed that the deep wells are extracting groundwater (Figure 6.3). The drawdown in the model for the surficial aquifer (Layer 1) is used to determine the impact of the tunnel on the alluvial wells.

6.3.1 Scenario #1 – West Tunnel Alignment, Expected Infiltration during Construction

Using an expected tunnel infiltration rate of 2,050 gpm during construction, the model indicates that the maximum drawdown caused by the tunnel will be almost five (5) feet within the deep carbonate layer (Layer 4) adjacent to the West tunnel alignment (Figure 6.4). Due to the resistance to vertical flow, the drawdown is less in the upper aquifer layers. Near the Riverside and White River wellfields, the maximum drawdown in Layers 1 and 2 is approximately 0.7 feet with these expected infiltration rates during construction.

6.3.2 Scenario #2 – Central Tunnel Alignment, Expected Infiltration during Construction

The maximum drawdown within the deep carbonate aquifer near the Central tunnel alignment is approximately 7.7 feet (Figure 6.5). Within the surficial aquifer and shallow carbonate aquifer, the maximum drawdown is approximately 1.7 feet. This occurs south of the Riverside and White River wellfields as shown on Figure 6.6. Near the Indianapolis Water's wells, the drawdown in the shallow surficial and carbonate aquifers is less than one (1) foot.

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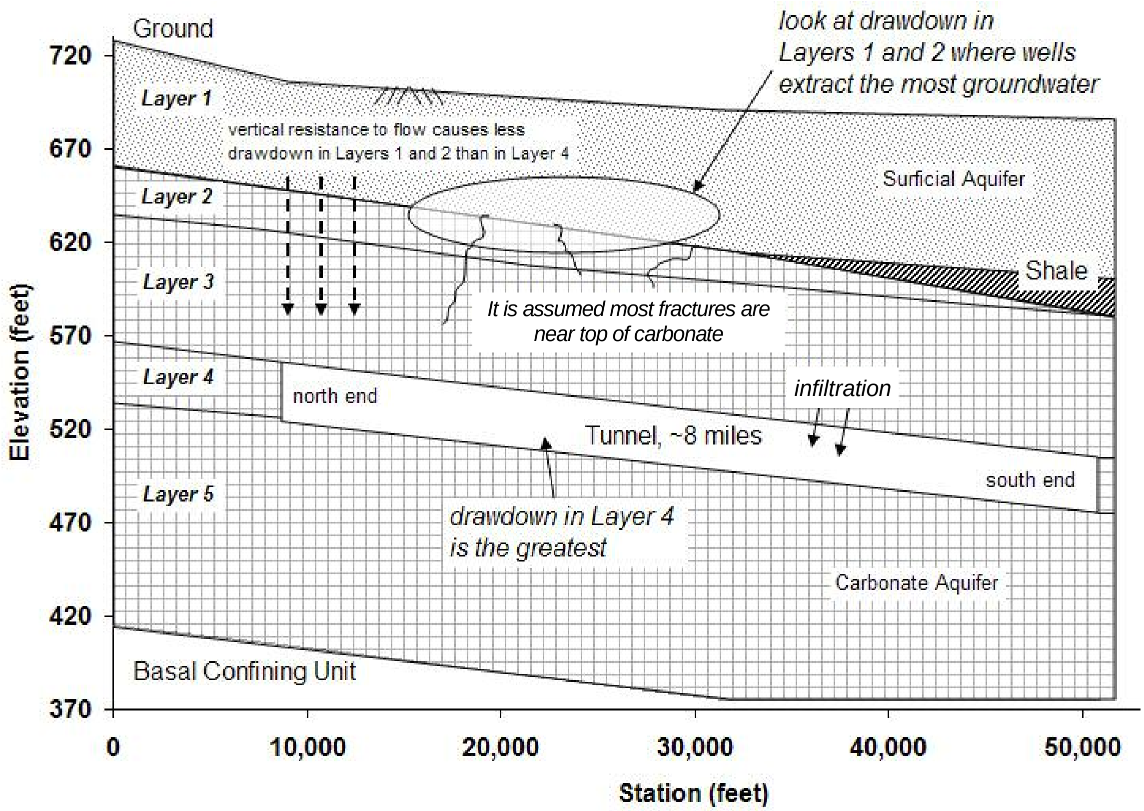

Figure 6.3 Use of Model Results to Determine Drawdown near Wells

6. ALTERNATIVE SCENARIOS

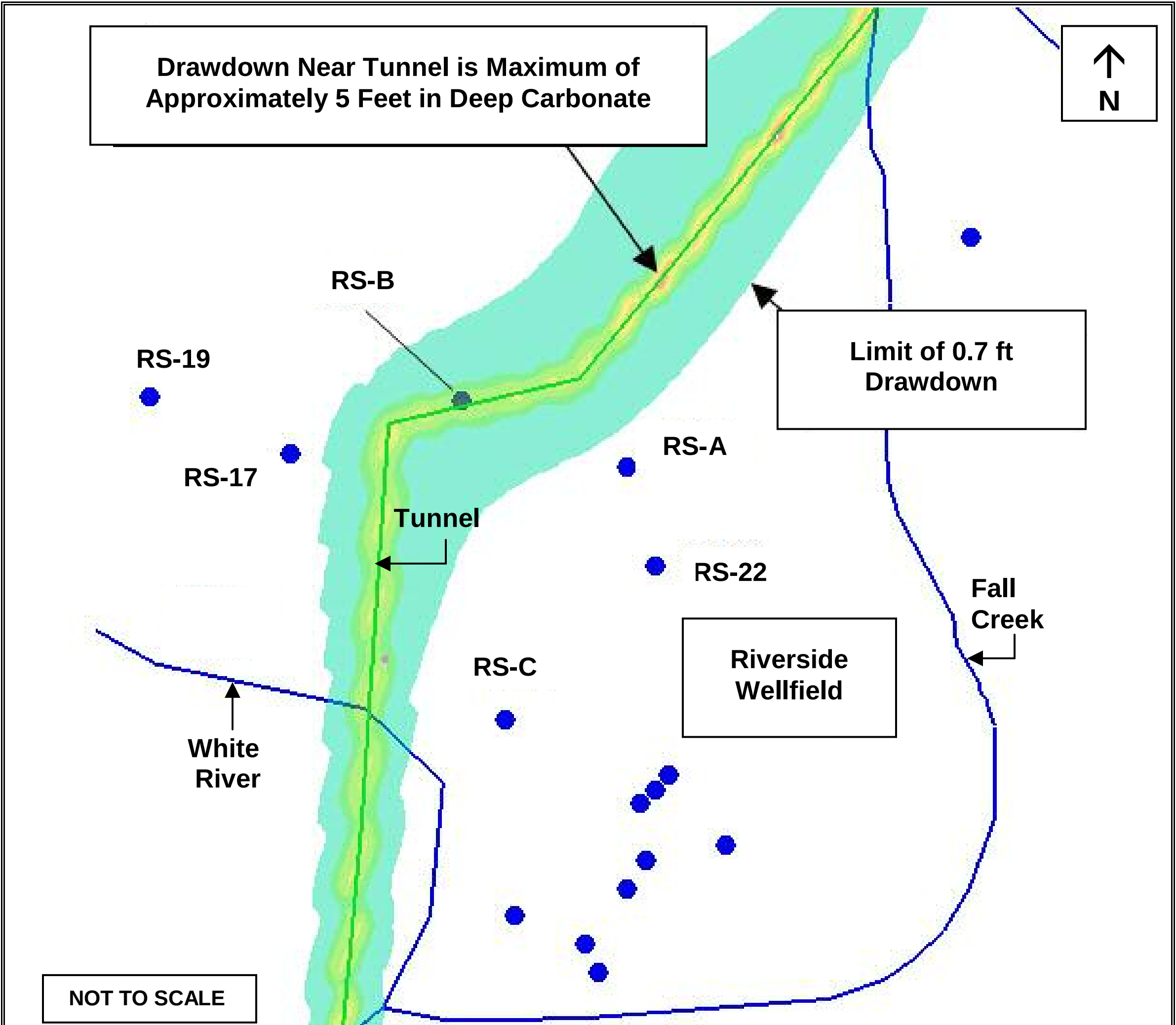

Figure 6.4 Scenario 1 – West Tunnel Alignment, Expected Infiltration During Construction

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

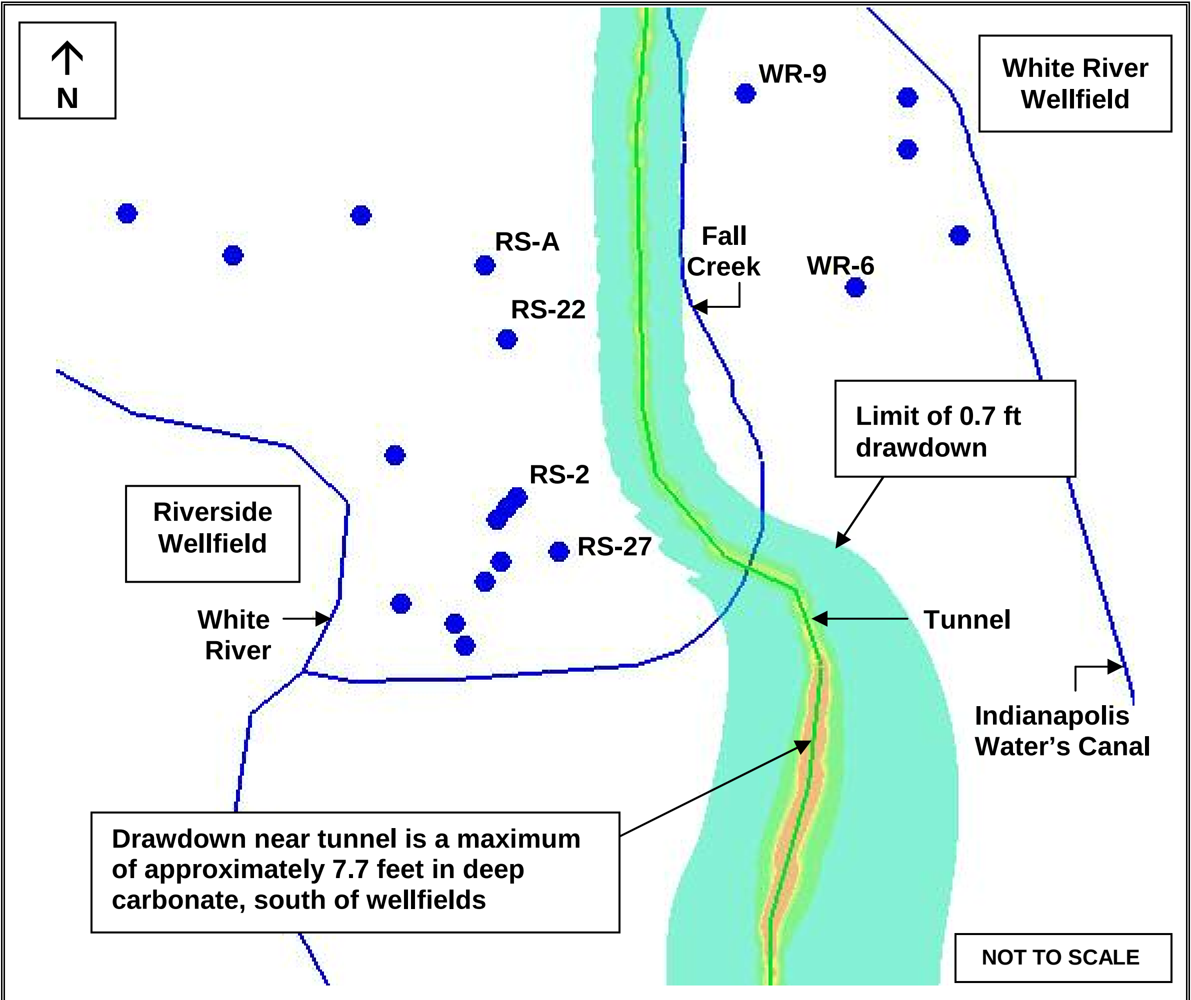

Figure 6.5 Scenario 2 – Central Tunnel Alignment, Expected Infiltration During Construction

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

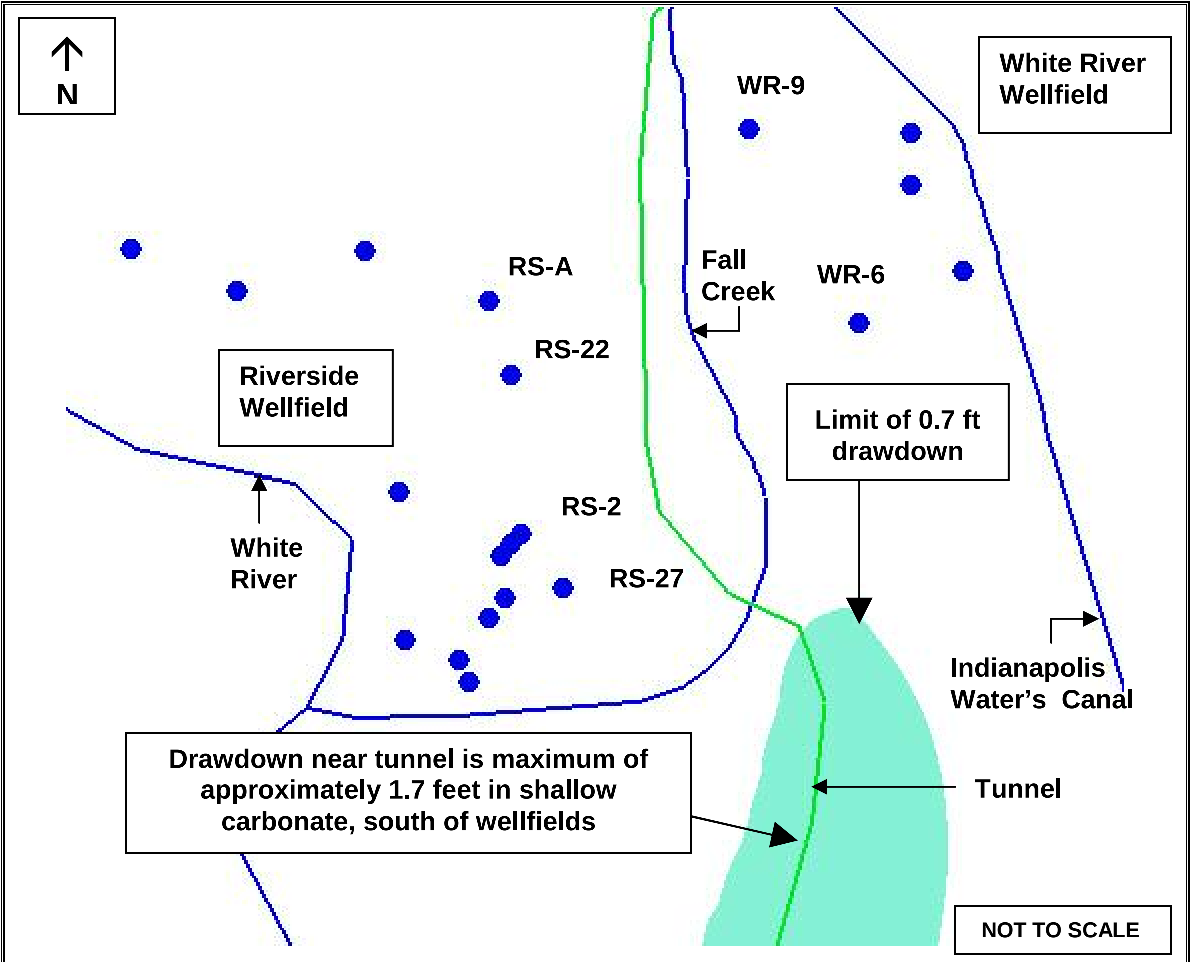

Figure 6.6 Scenario 2 – Central Tunnel Alignment,
Expected Infiltration During Construction
Drawdown Caused by Tunnel in Shallow Carbonate (Model Layer 2)

6. ALTERNATIVE SCENARIOS

6.3.3 Scenario #3 – East Tunnel Alignment, Expected Infiltration during Construction

In the deep carbonate aquifer, the tunnel causes a maximum drawdown of approximately 9.2 feet adjacent to the East tunnel alignment to the south of the White River wellfield during construction (Figure 6.7). The drawdown in the shallow carbonate and surficial aquifers near the White River wellfield is approximately one (1) foot or less as indicated on Figures 6.8 and 6.9.

6.3.4 Scenario #4 – West Tunnel Alignment, High Infiltration during Construction

The model shows that if the higher estimates of tunnel infiltration were to occur during construction along the West tunnel alignment, the drawdown in the deep carbonate aquifer would be as high as approximately 15.5 feet (Figure 6.10). For the shallow aquifer layers, the reduction in groundwater levels would be a maximum of approximately two (2) feet near some of the wells within the Riverside wellfield (Figure 6.11).

6.3.5 Scenario #5 – Central Tunnel Alignment, High Infiltration during Construction

The model shows a maximum drawdown of up to 25 feet for the deep carbonate aquifer adjacent to the Central tunnel alignment (Figure 6.12). However, near the Riverside and White River wellfields, the drawdown is approximately 1 to 2 feet (Figure 6.12). Within the shallow aquifer layers, the drawdown in groundwater levels is between approximately 1 and 2 feet at several of the well locations as indicated on Figure 6.13.

6. ALTERNATIVE SCENARIOS

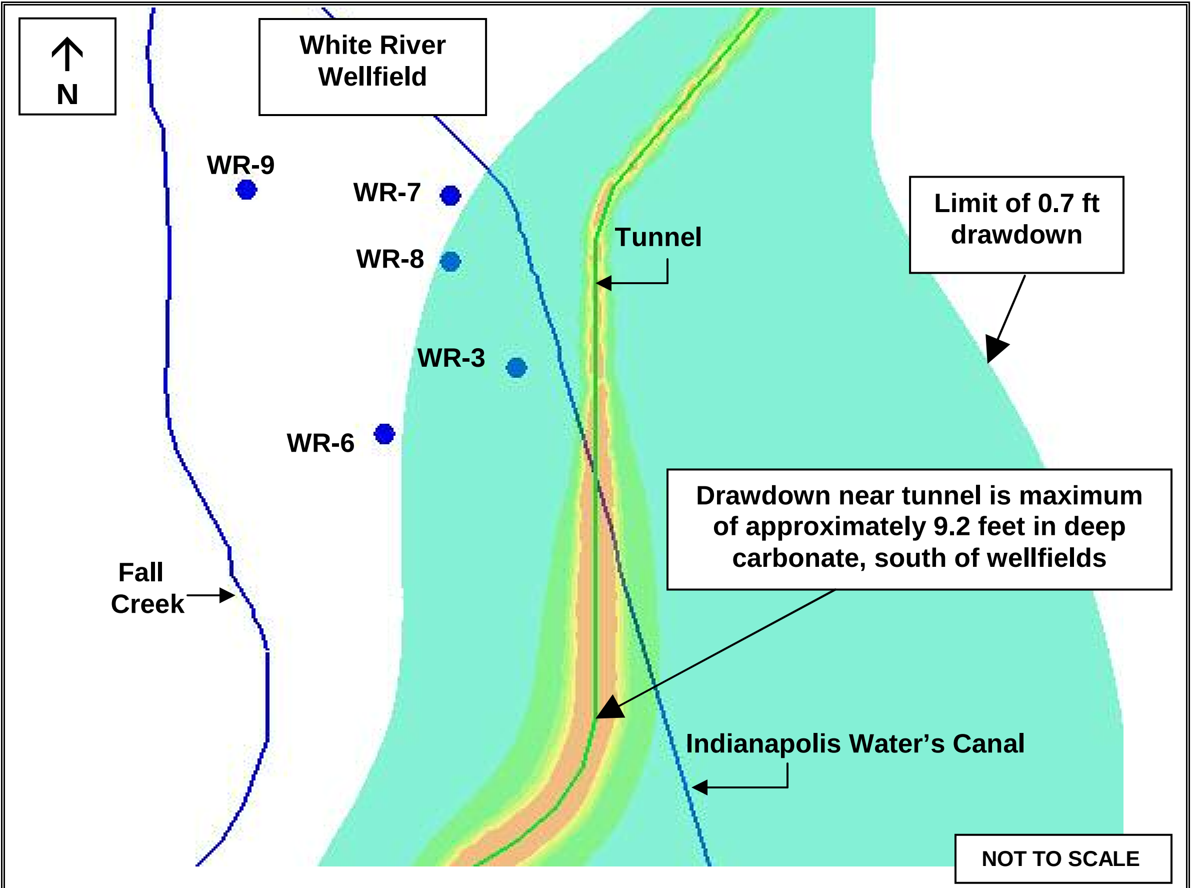

Figure 6.7 Scenario 3 – East Tunnel Alignment, Expected Infiltration During Construction
Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

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6. ALTERNATIVE SCENARIOS

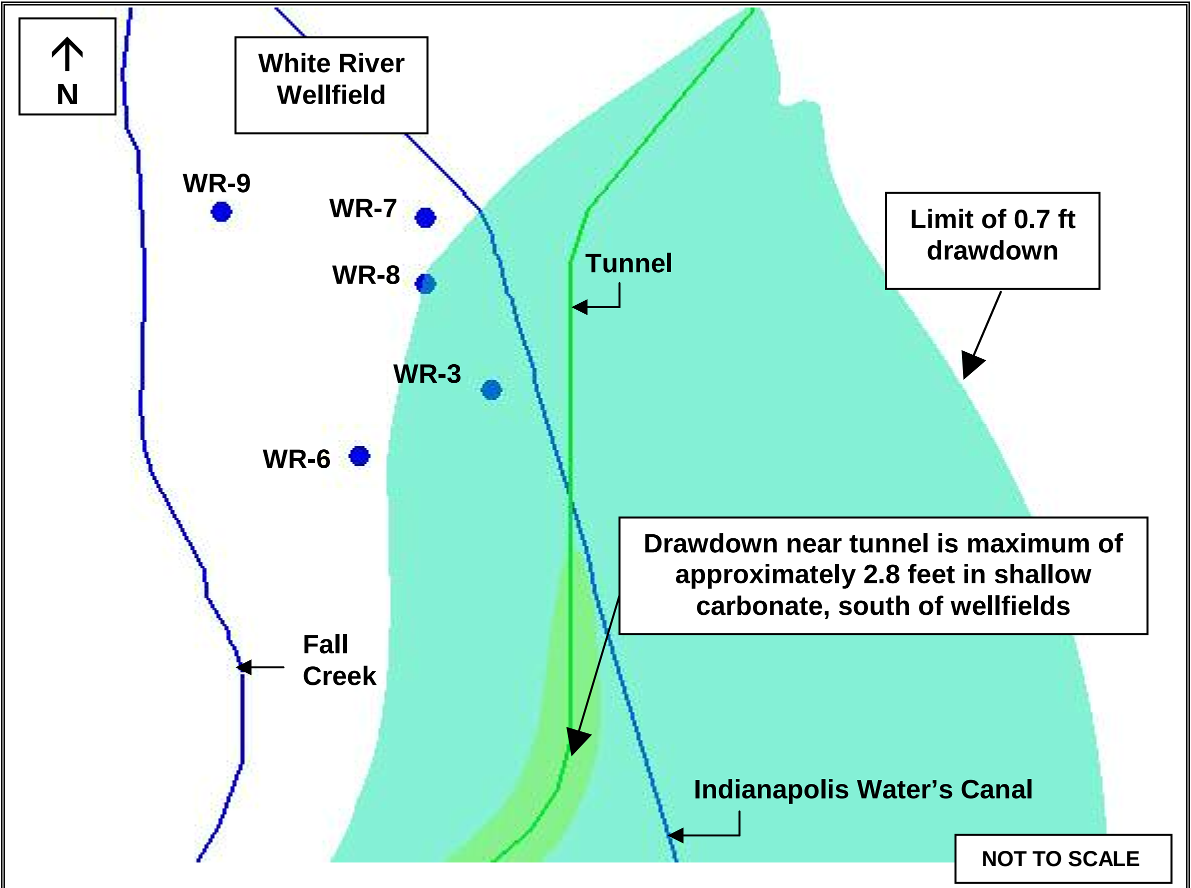

Figure 6.8 Scenario 3 – East Tunnel Alignment, Expected Infiltration During Construction

Drawdown Caused by Tunnel in Shallow Carbonate (Model Layer 2)

6. ALTERNATIVE SCENARIOS

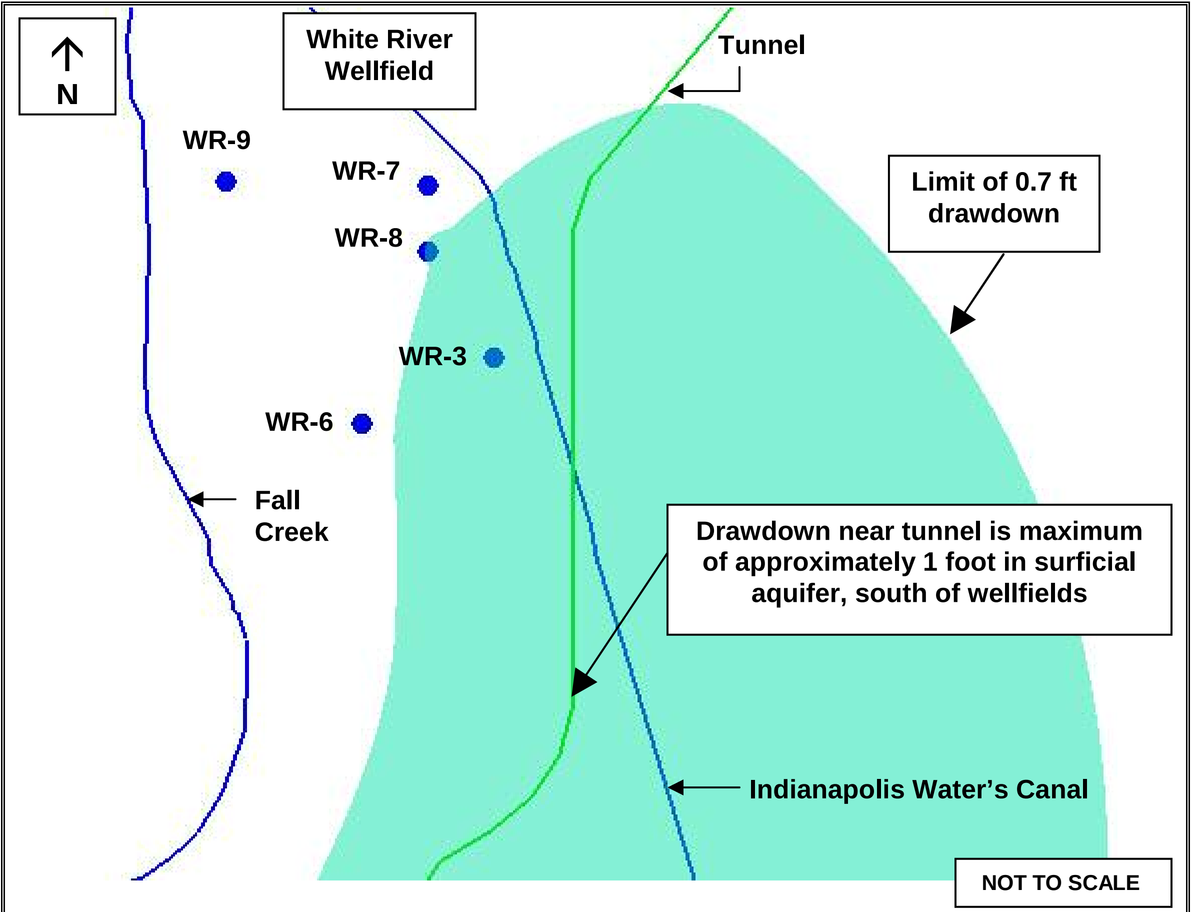

Figure 6.9 Scenario 3 – East Tunnel Alignment, Expected Infiltration During Construction

Drawdown Caused by Tunnel in Surficial Aquifer (Model Layer 1)

6. ALTERNATIVE SCENARIOS

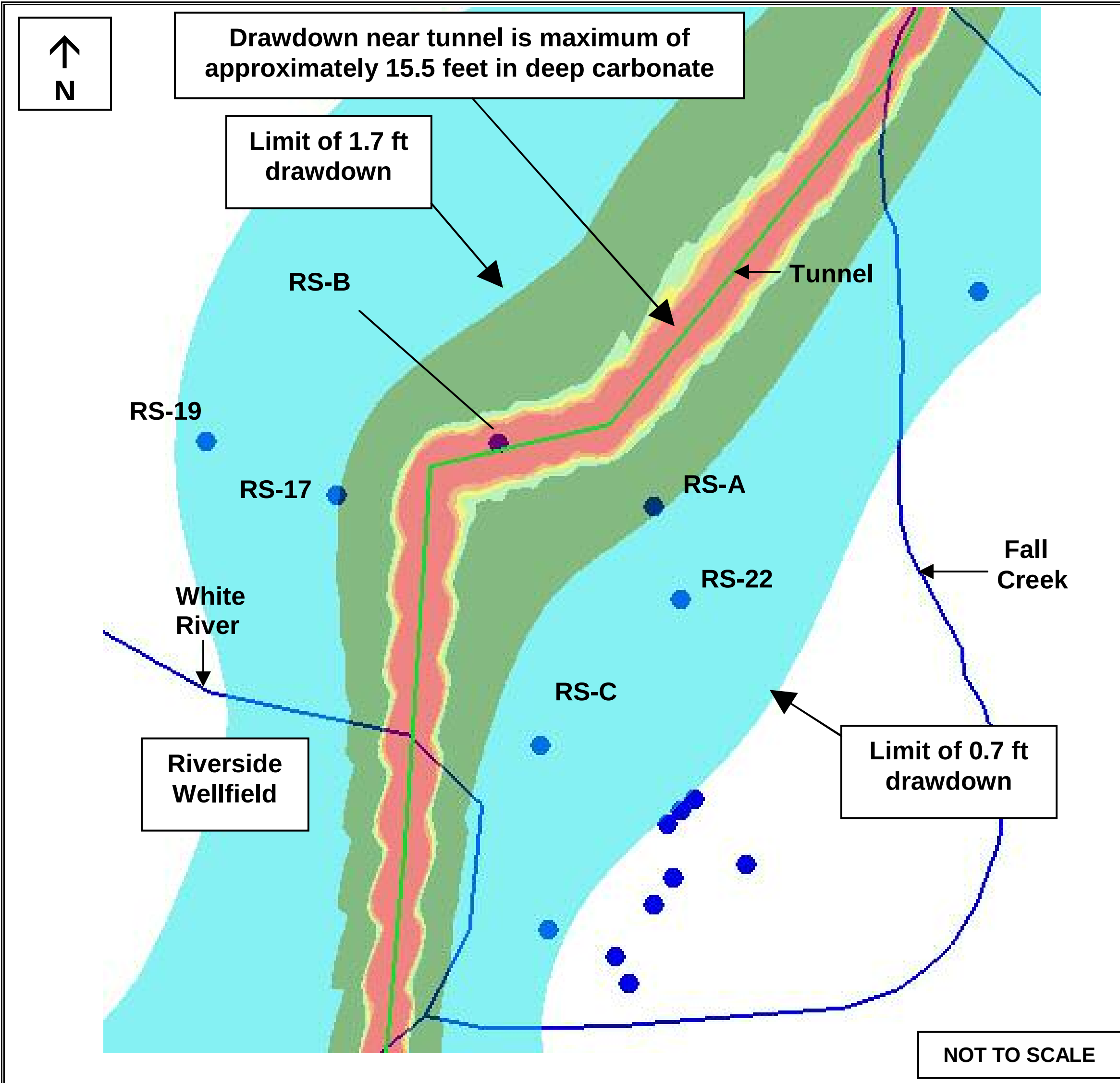

Figure 6.10 Scenario 4 – West Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

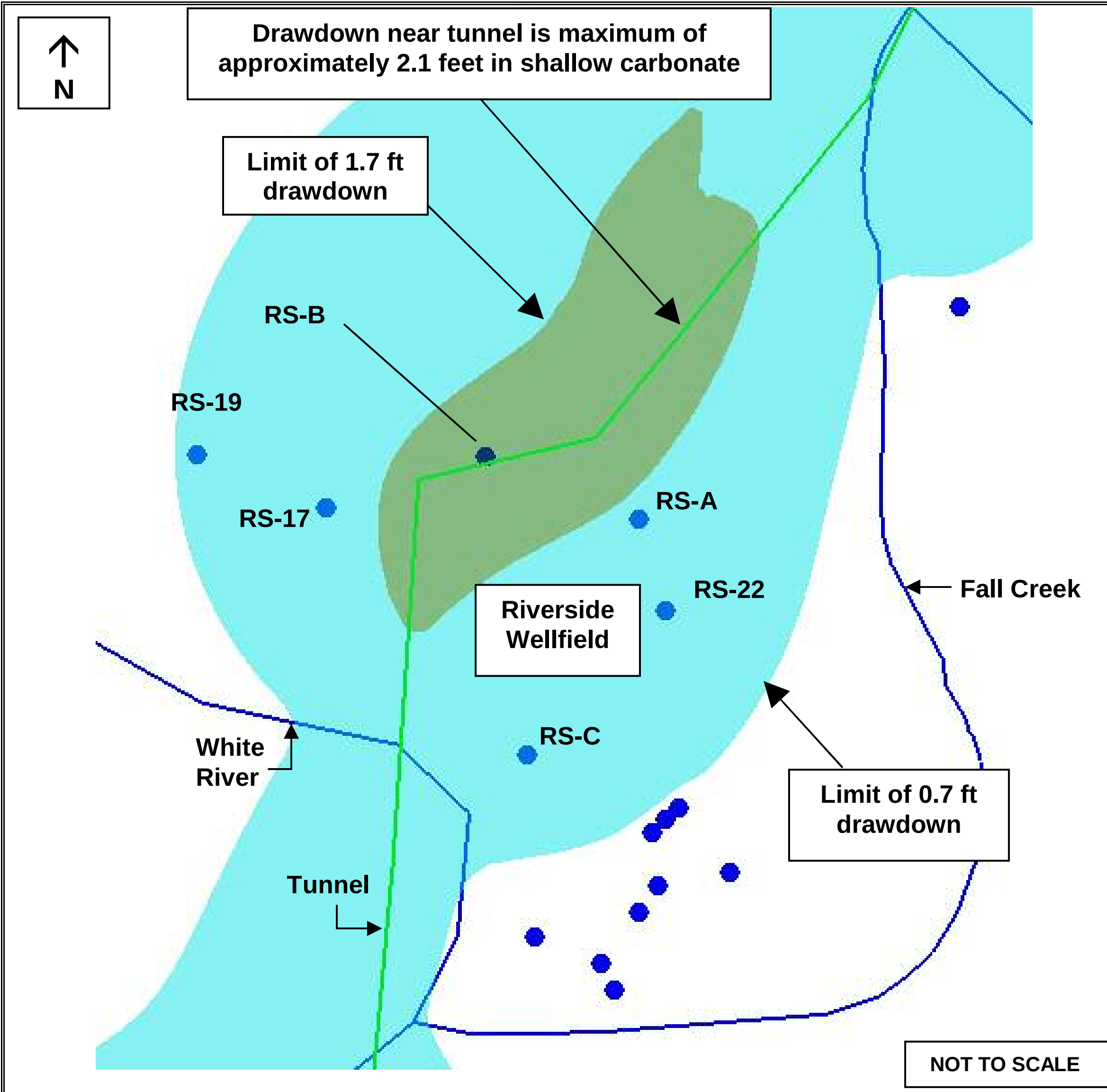

Figure 6.11 Scenario 4 – West Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Shallow Carbonate (Model Layer 2)

6. ALTERNATIVE SCENARIOS

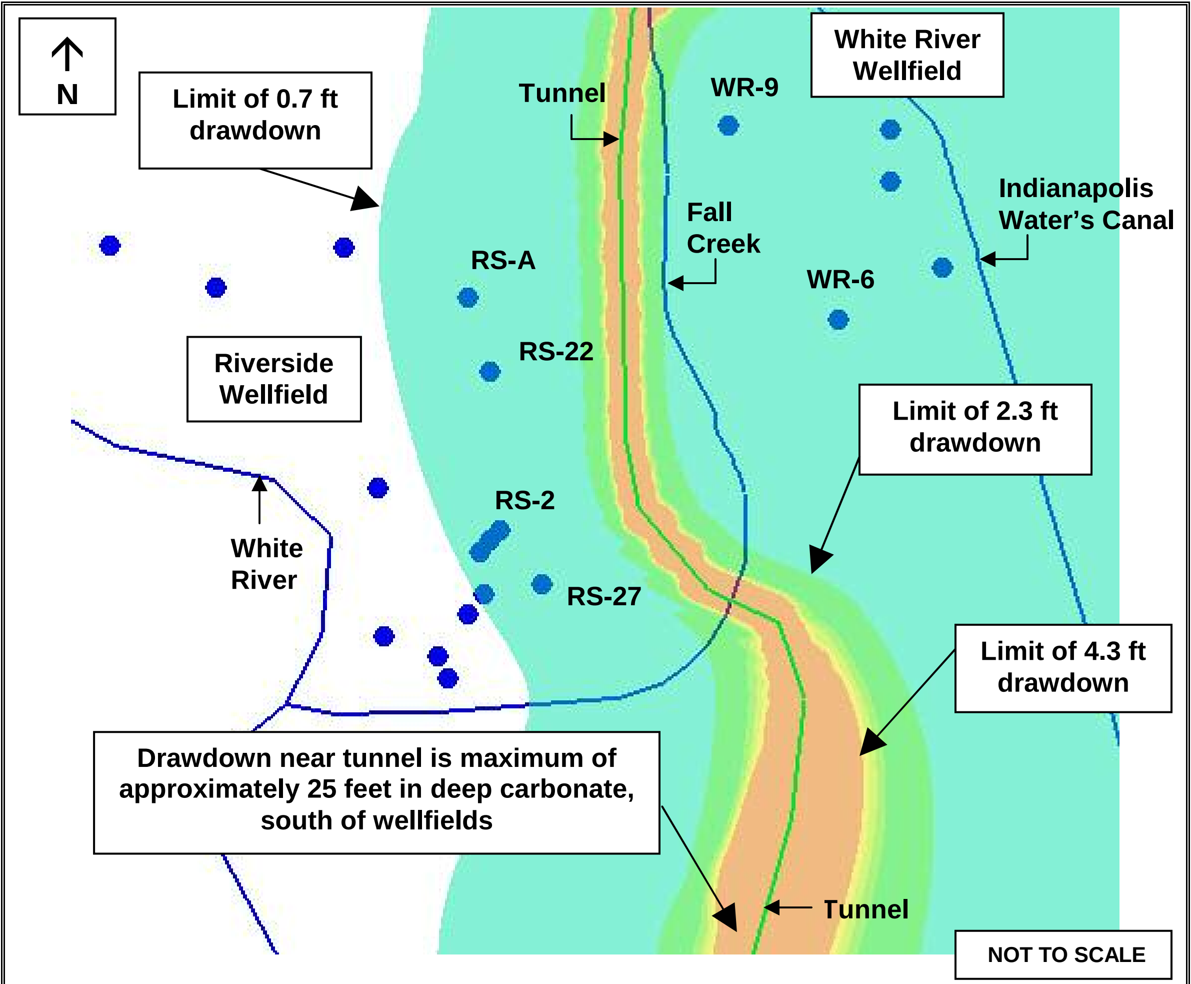

Figure 6.12 Scenario 5 – Central Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

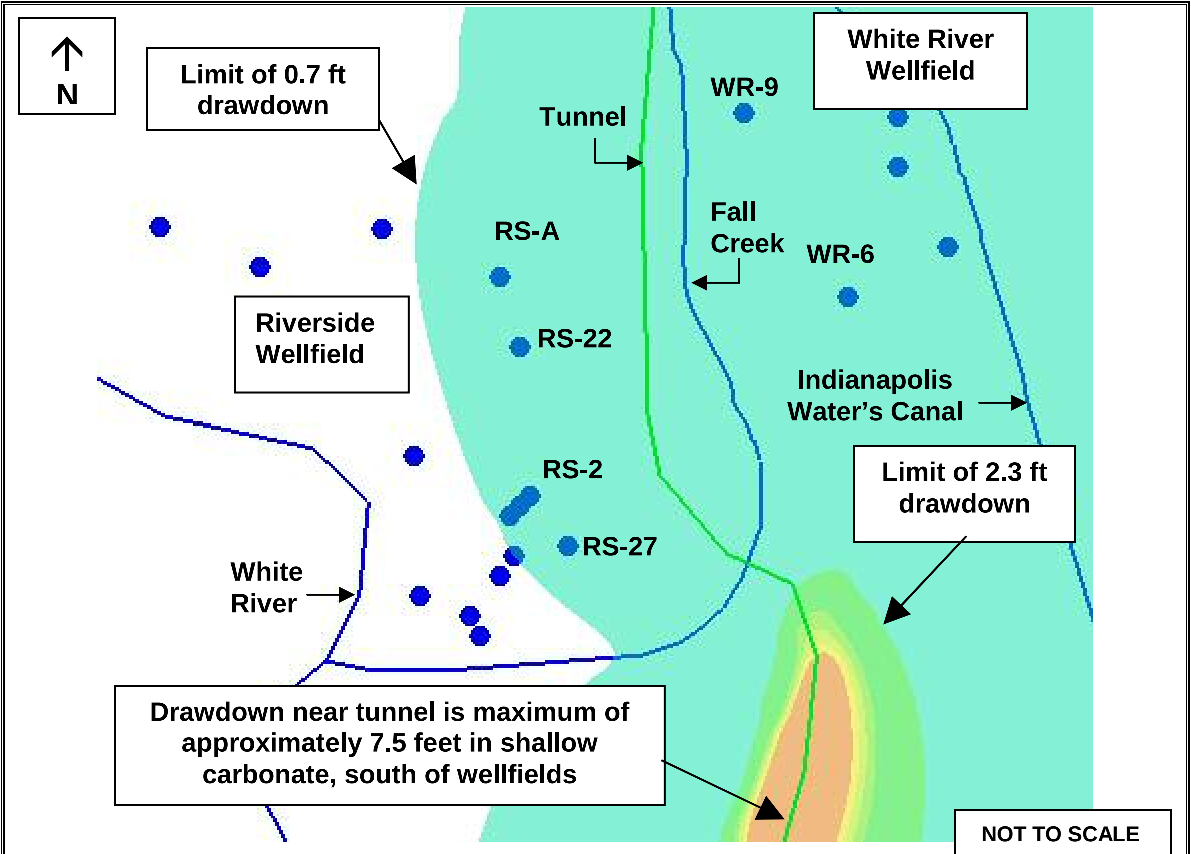

Figure 6.13 Scenario 5 – Central Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Shallow Carbonate (Model Layer 2)

6.3.6 Scenario #6 – East Tunnel Alignment, High Infiltration during Construction

The maximum drawdown in the deep carbonate is nearly 30 feet along the East tunnel alignment south of the White River wellfield (Figure 6.14). In the surficial aquifer, the drawdown is approximately 1 to 3 feet, as shown on Figure 6.15.

6.3.7 Scenarios #7, #8, and #9 – West, Central, and East Tunnel Alignments, respectively, Expected Infiltration during Operation

The drawdown caused by these scenarios in the surficial and shallow carbonate aquifers is less than one (1) foot. In the deep carbonate, the drawdown is 1 to 3 feet. Figure 6.16 shows a typical drawdown for one of these scenarios along the east tunnel alignment. By distributing the estimated infiltration rate of 520 gpm along the entire length of the tunnel, the impact of the tunnel on groundwater levels during long-term operation is minimal.

6.3.8 Scenario #10, #11, and #12 – West, Central, and East Tunnel Alignments, respectively, High Infiltration during Operation

The groundwater levels for the deep carbonate aquifer are drawn down by 4 to 7 feet for long-term tunnel operation with the high estimates of infiltration, as shown by Figures 6.17, 6.18, and 6.19. The drawdown caused in the surficial and shallow carbonate aquifers is less than one (1) foot, as shown in Figures 6.20 and 6.21.

6.3.9 Impact on Existing Wells

Figure 6.22 shows the known existing production wells along the preliminary tunnel alignments. Table 6.3 provides the drawdown calculated by the model for the scenarios with the highest infiltration rates estimated for each of the tunnel alignments. The East tunnel alignment impacts the most wells in the area by several

6. ALTERNATIVE SCENARIOS

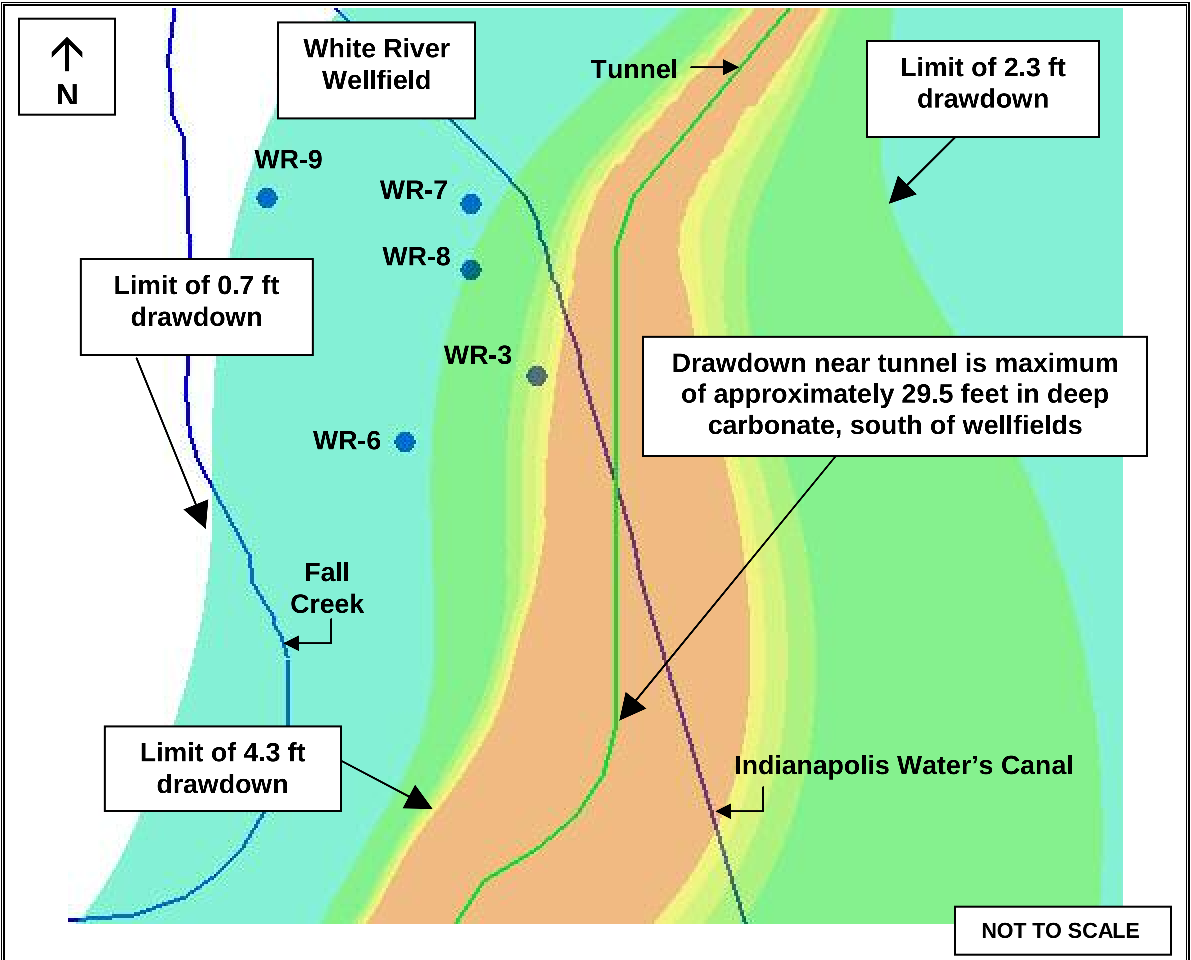

Figure 6.14 Scenario 6 – East Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

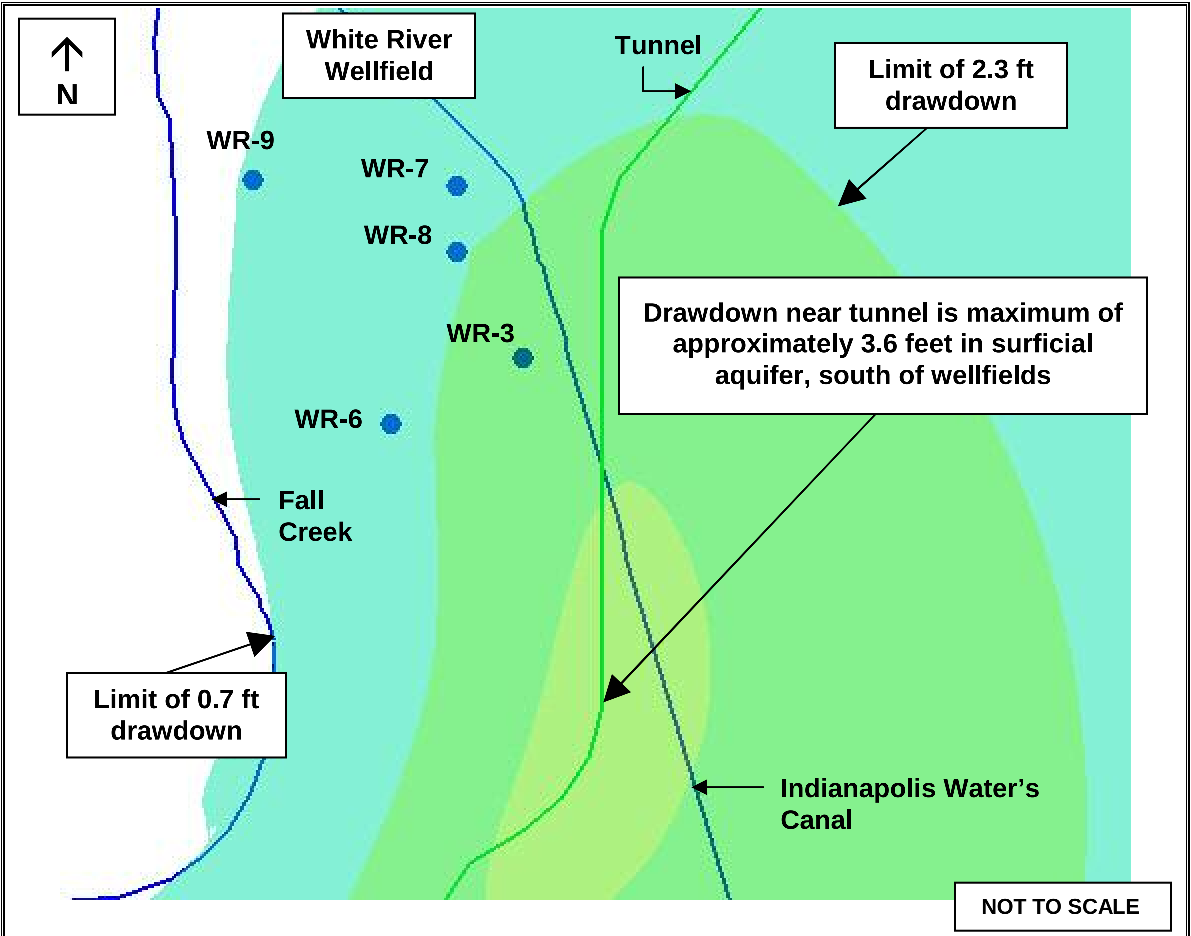

Figure 6.15 Scenario 6 – East Tunnel Alignment, High Infiltration During Construction

Drawdown Caused by Tunnel in Surficial Aquifer (Model Layer 1)

6. ALTERNATIVE SCENARIOS

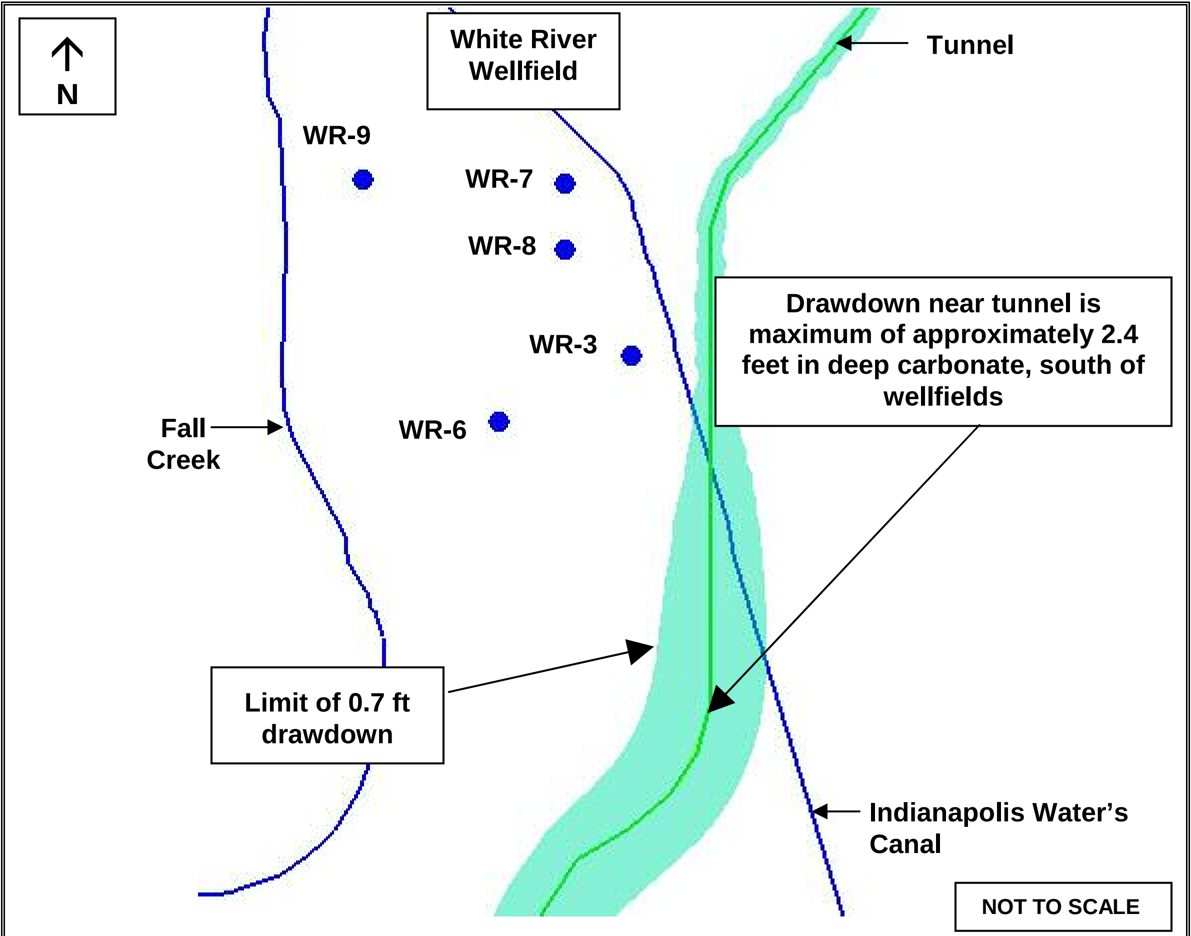

Figure 6.16 Scenario 9 – East Tunnel Alignment, Expected Infiltration During Operation

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

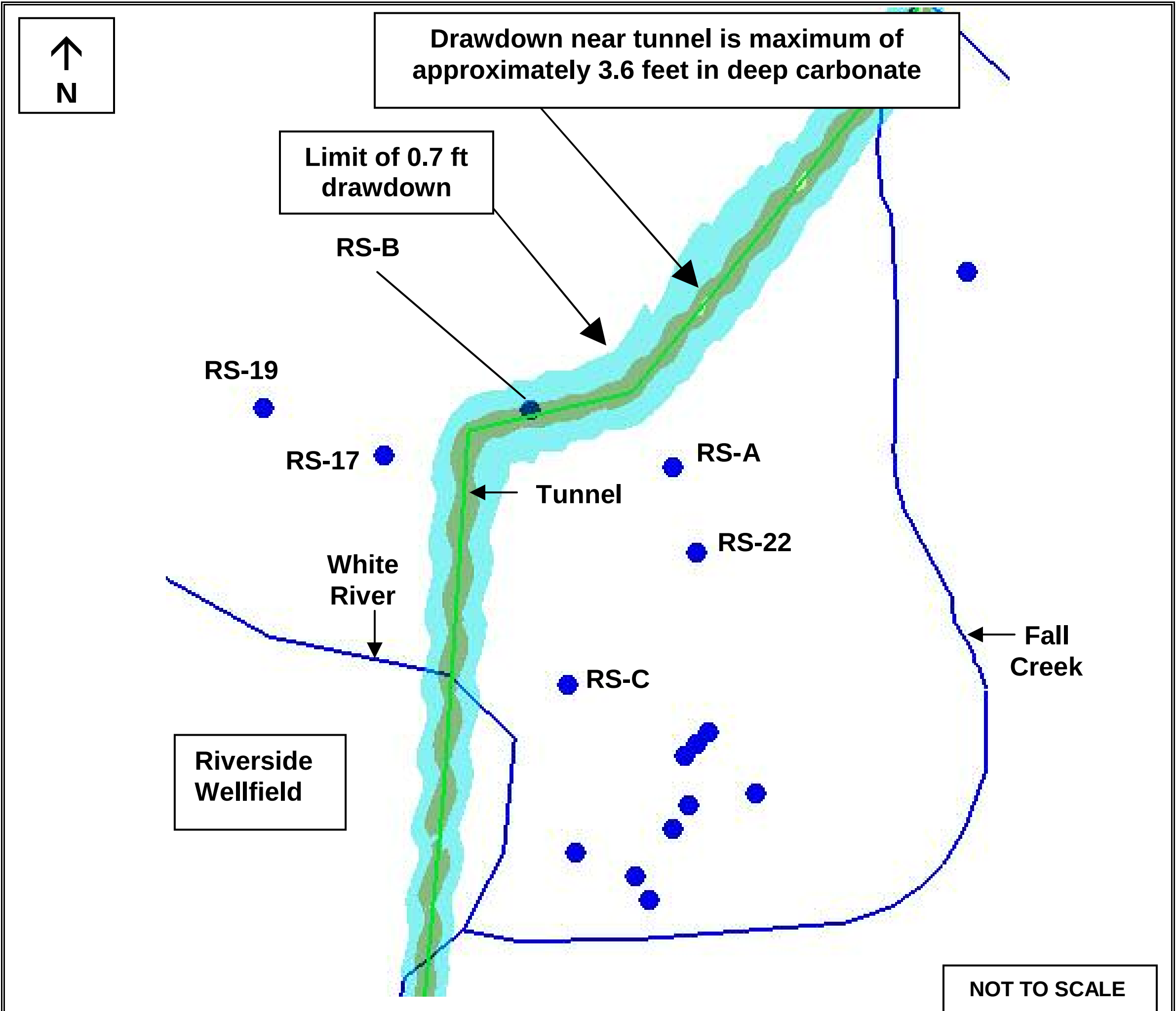

Figure 6.17 Scenario 10 – West Tunnel Alignment, High Infiltration During Operation

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

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6. ALTERNATIVE SCENARIOS

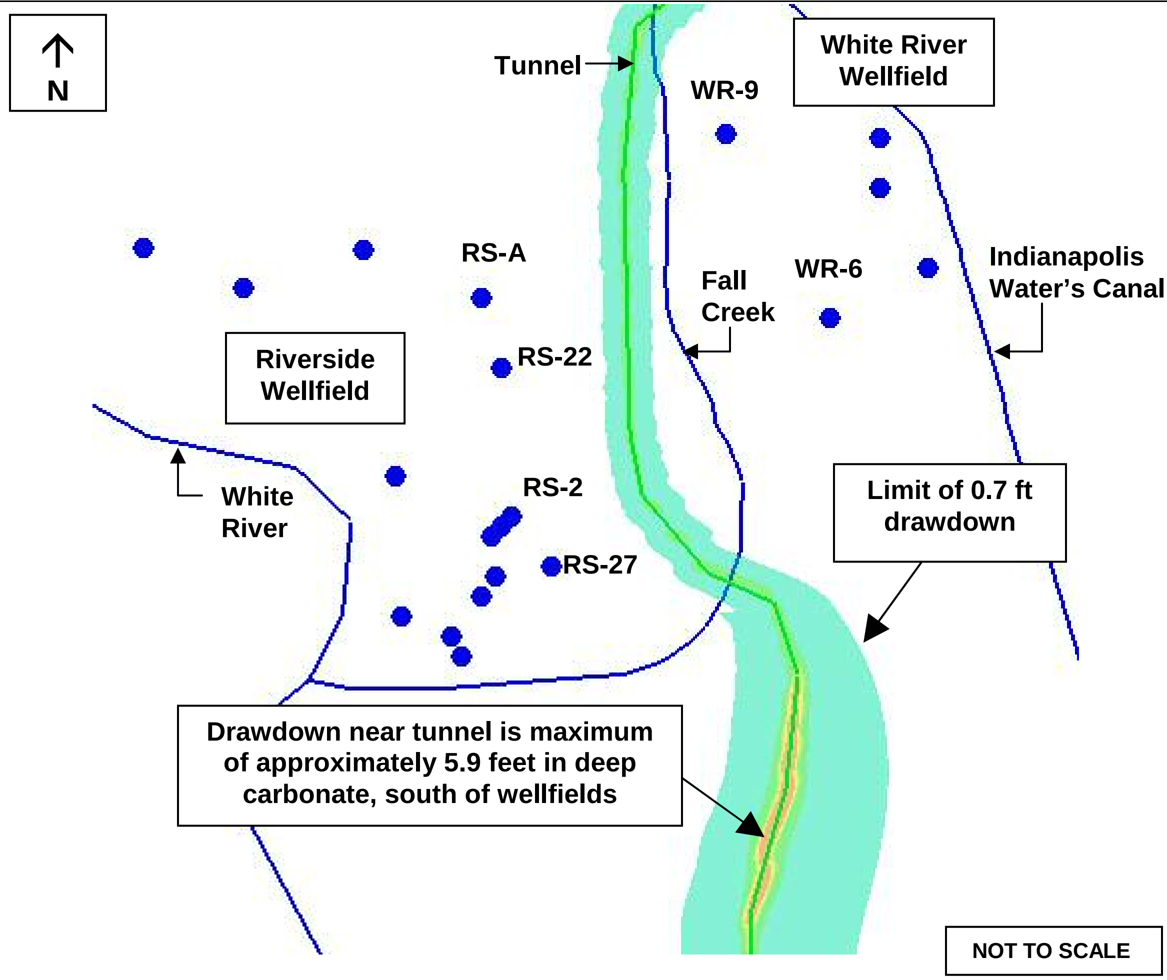

Figure 6.18 Scenario 11 – Central Tunnel Alignment, High Infiltration During Operation

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

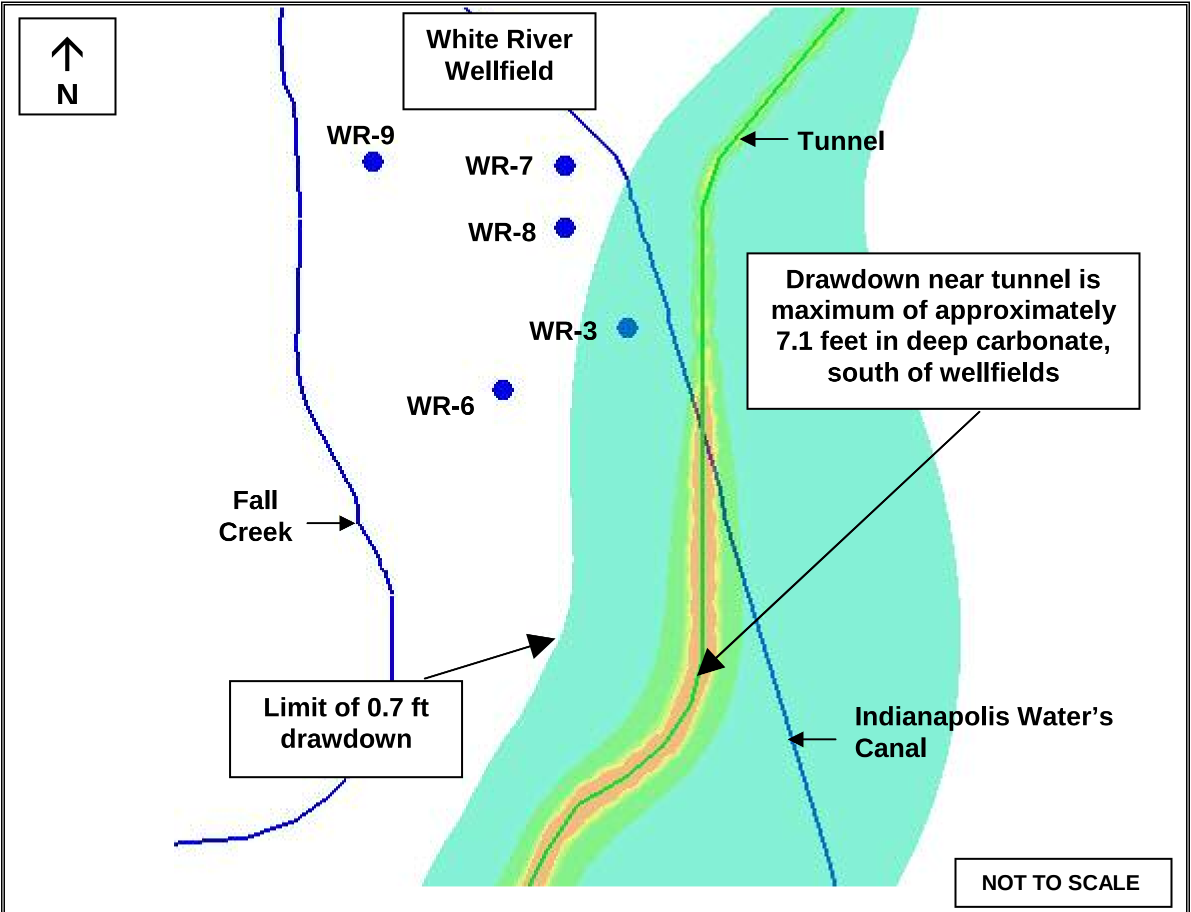

Figure 6.19 Scenario 12 – East Tunnel Alignment, High Infiltration During Operation

Drawdown Caused by Tunnel in Deep Carbonate (Model Layer 4)

6. ALTERNATIVE SCENARIOS

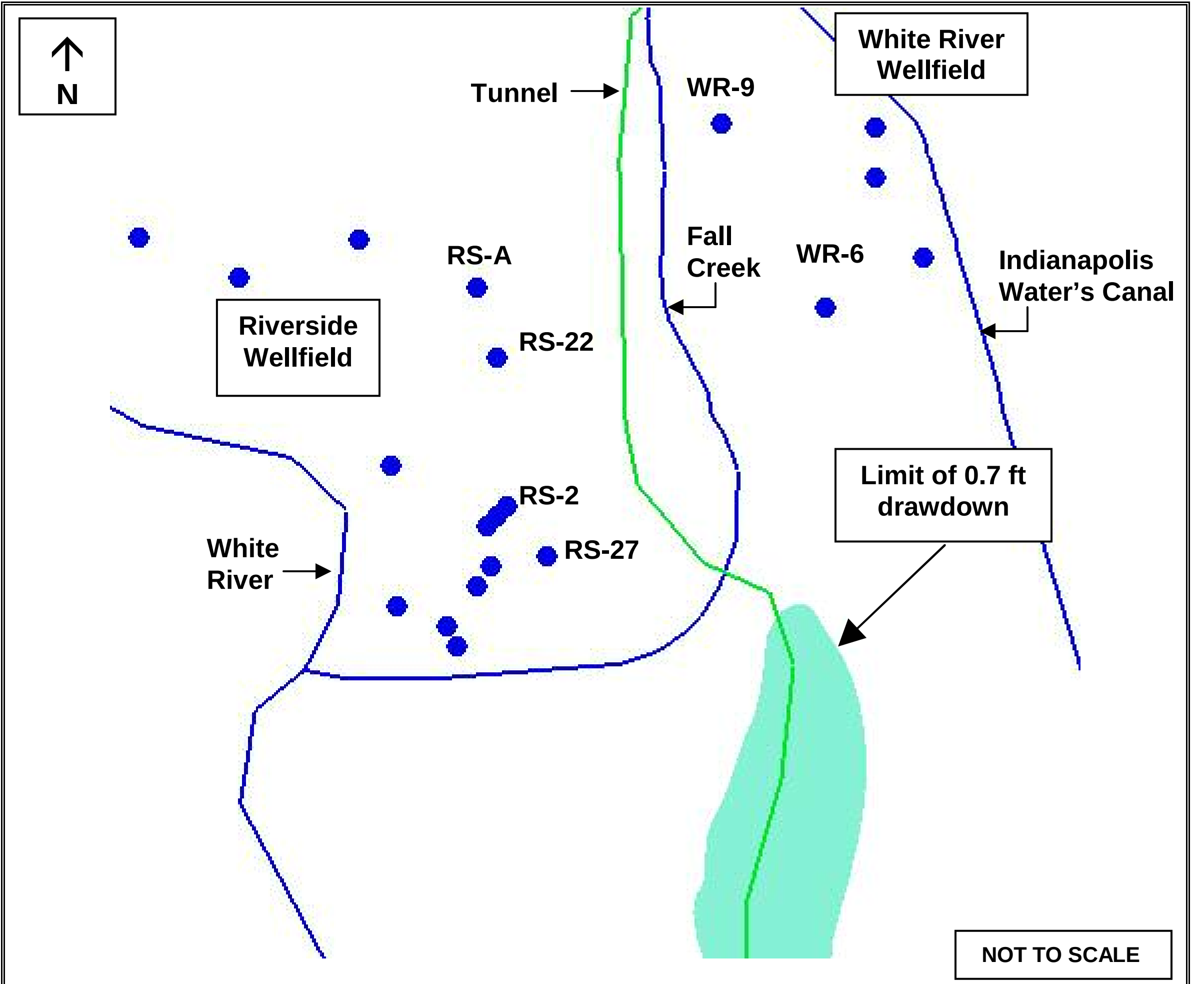

Figure 6.20 Scenario 11 – Central Tunnel Alignment, High Infiltration During Operation

Drawdown Caused by Tunnel in Shallow Carbonate (Model Layer 2)

6. ALTERNATIVE SCENARIOS

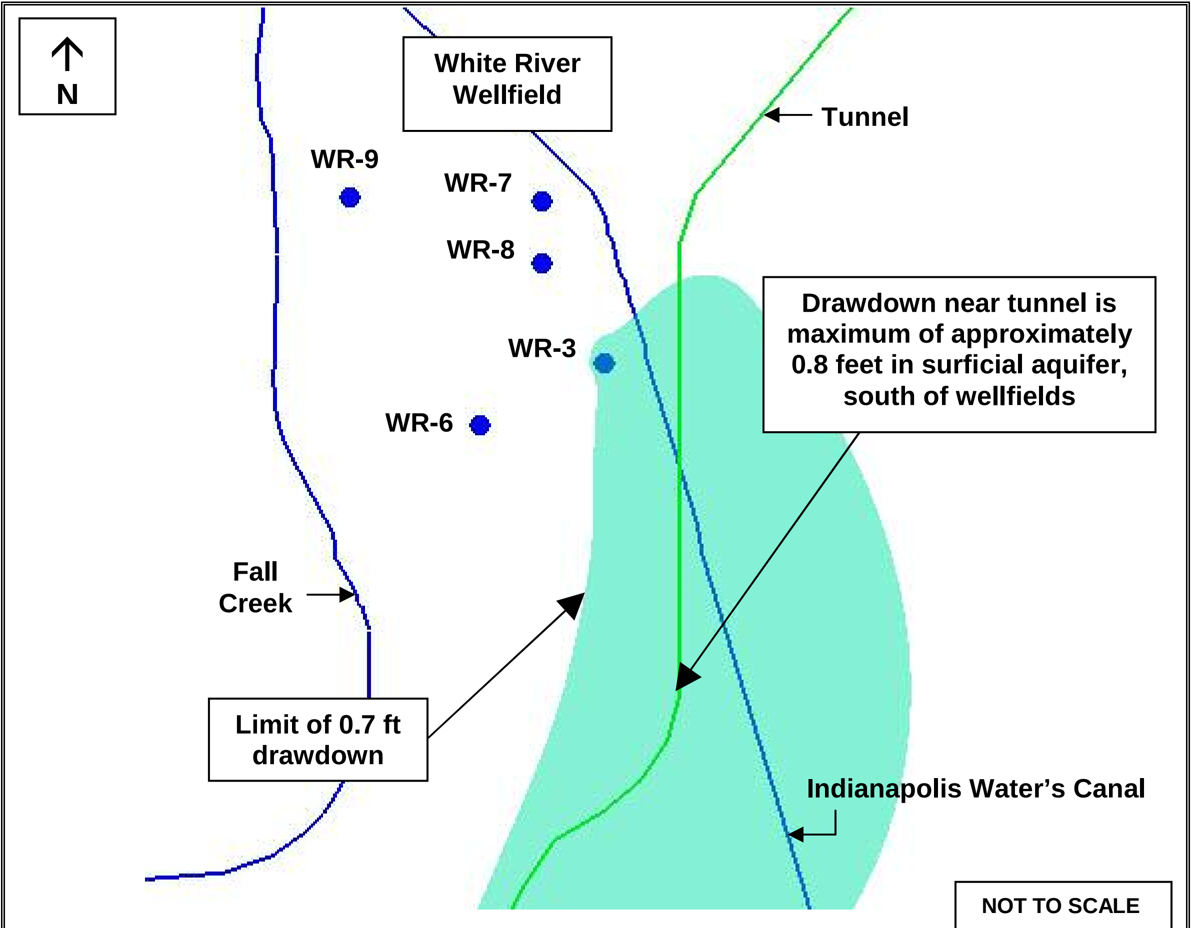

Figure 6.21 Scenario 12 – East Tunnel Alignment, High Infiltration During Operation

Drawdown Caused by Tunnel in Surficial Aquifer (Model Layer 1)

6. ALTERNATIVE SCENARIOS

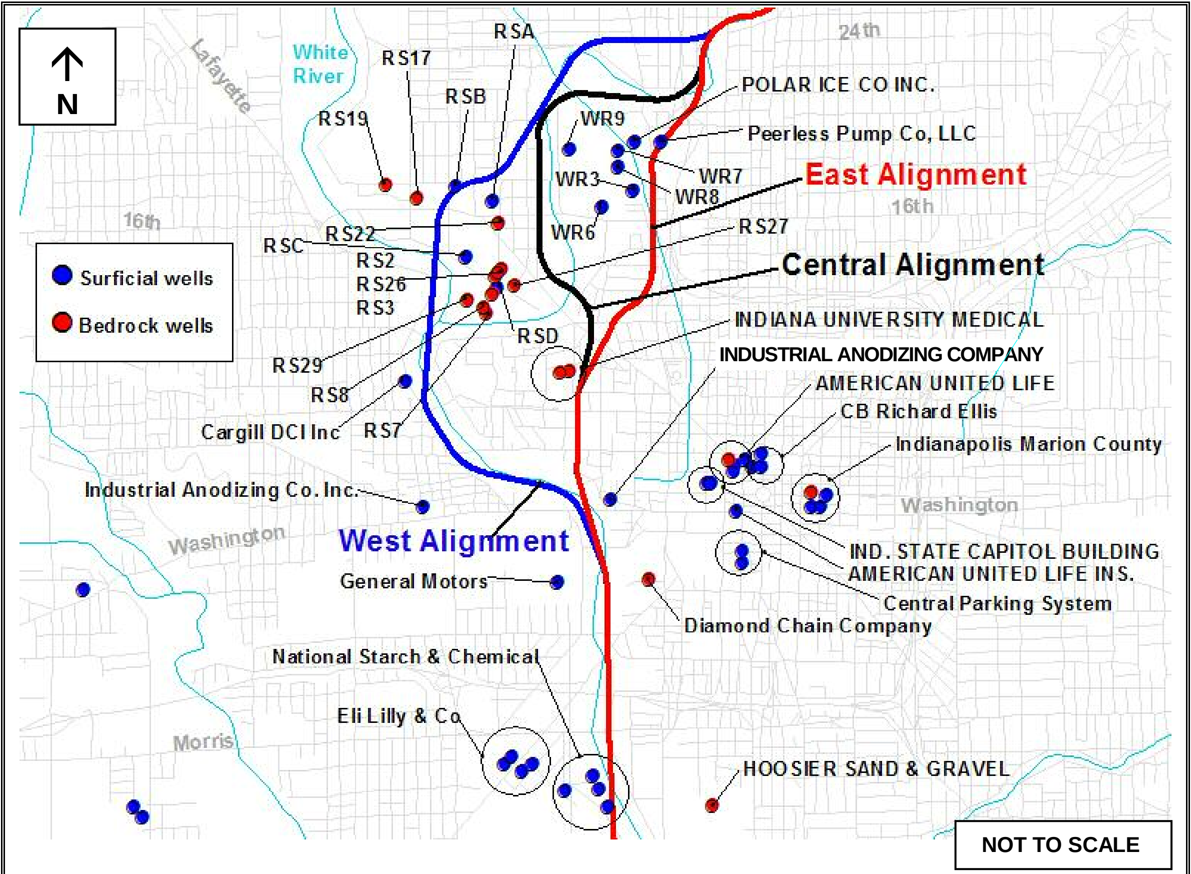

Figure 6.22 Existing Wells along Tunnel Alignments

6. ALTERNATIVE SCENARIOS

Table 6.3
Drawdown (ft) During Construction
(assuming high infiltration rates)

Well Identification	Model Layer	Tunnel Alignment		
		West (Scen. #4)	Central (Scen. #5)	East (Scen. #6)
RS-A	1, surficial	1.4	*	*
RS-B	1, surficial	1.7	*	*
RS-C	1, surficial	*	*	*
RS-D	1, surficial	*	*	*
RS-2	2, carbonate	*	*	*
RS-3	2, carbonate	*	*	*
RS-7	2, carbonate	*	*	*
RS-8	2, carbonate	*	*	*
RS-9	2, carbonate	*	*	*
RS-17	2, carbonate	1.3	*	*
RS-19	2, carbonate	*	*	*
RS-22	2, carbonate	1.0	*	*
RS-26	2, carbonate	*	*	*
RS-27	2, carbonate	*	*	*
RS-29	2, carbonate	*	*	*
WR-3	1, surficial	*	1.3	3.1
WR-6	1, surficial	*	*	2.0
WR-7	1, surficial	*	*	2.0
WR-8	1, surficial	*	*	2.0
WR-9	1, surficial	*	*	2.3
Polar Ice Co.	1, surficial	*	1.2	2.0
Peerless Pump Co.	1, surficial	*	1.2	2.5
Indiana Univ. Medical	2, carbonate	*	3.7	3.7
Cargill	1, surficial	*	*	*
Industrial Anodizing	1, surficial	1.1	*	*
Industrial Anodizing	1, surficial	*	1.5	1.8
General Motors	1, surficial	*	1.0	1.0

* less than 1 foot of drawdown

Table 6.3 cont. Drawdown (ft) During Construction (assuming high infiltration rates)				
Well Identification	**Model Layer**	**Tunnel Alignment**		
		West (Scen. #4)	**Central (Scen. #5)**	**East (Scen. #6)**
Diamond Chain Co.	2, carbonate	*	1.1	1.3
Eli Lilly & Co.	1, surficial	1.0	*	1.0
National Starch & Chem.	1, surficial	1.0	1.0	1.1
Hoosier Sand & Gravel	2, carbonate	*	*	*
Amer. United Life	1, surficial	*	1.6	2.4
Amer. United Life	2, carbonate	*	1.3	2.0
CB Richard Ellis	1, surficial	*	1.5	2.2
Ind. Marion Co.	1, surficial	*	1.2	1.9
Ind. Marion Co.	2, carbonate	*	1.2	1.8
Ind. State Capitol Bldg.	1, surficial	*	1.6	2.3
Central Parking System	1, surficial	*	1.3	1.8
Maximum Drawdown at a Well		**1.7 ft**	**3.7 ft**	**3.7 ft**
* less than 1 foot of drawdown				

feet, while the West tunnel alignment impacts the fewest wells. The East alignment does not follow beneath the White River or Fall Creek for as much of its length as the other alignments. Due to that difference in the East alignment, it appears the streams cannot provide as much recharge to offset the drawdown causing a greater impact to groundwater levels.

6.3.10 Higher Summertime Pumping Rates from City Wells

The calibration of the groundwater model and evaluation of the various tunnel scenarios used annual average pumping rates reported to IDNR from 2000 through 2004 for the Indianapolis Water's wells. Higher summertime pumping rates were provided by Veolia Water for the Riverside, White River, and Fall Creek wellfields to be evaluated using the groundwater model. This was modeled to address concerns about whether the drawdown caused by the tunnel would be more extreme during times when the wells are being pumped at higher rates. Most of the summer pumping rates matched the reported pump capacities for the well, and Veolia Water confirmed that there are times when all of the wells are pumping together at high rates. A comparison of the higher summer pumping rates to the total average pumping rates determined from IDNR records from 2000 through 2004 is shown in Table 6.4. The total summer pumping rate from the three (3) wellfields is 26,561 gpm, which is more than double the total annual average pumping rate from the wellfields of 12,771 gpm.

Groundwater models were developed for both existing and future conditions using the higher summer pumping rates. For future conditions, the West tunnel alignment with the high tunnel infiltration rate scenario was evaluated. The drawdown caused by the tunnel with summer pumping rates was compared to the drawdown caused by the same scenario with the average pumping rates. The model results showed that the drawdown using the higher rates was nearly identical to the drawdown using the average rates. This indicates that the net impact of tunnel infiltration on the City's wellfields will be similar regardless of whether the wells are being pumped at average or high rates.

The few feet of drawdown developed by the model would be a concern if the water level inside a well under existing conditions at high pumping rates is just above the pump intake or just above the top of a well screen. To determine if there is a concern, well data will need to be obtained and reviewed in future project phases for: 1) the pumping levels inside each well when all wells are pumping at their high rates, 2) the elevations of the tops of all well screens, and 3) the elevations for all of the well pumps.

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Table 6.4
Pumping Rates Evaluated for City Water Supply Wells

Well Identification	Aquifer	Pump Capacity (gpm)	Average IDNR Reported Pumping Rate, 2000-2004 (gpm)	Veolia Higher Summer Pumping Rate (gpm)
Fall Creek Wellfield				
FC-2	carbonate	1,000	563	1,000
FC-5	carbonate	400	261	400
FC-7	carbonate	800	309	800
FC-8	carbonate	600	256	600
FC-11	carbonate	1,000	509	1,000
FC-17	sand and gravel	700	149	700
FC-18	sand and gravel	1,400	1,161	1,400
FC-19	sand and gravel	700	347	700
FC-20	sand and gravel	1,050	102	1,050
FC-21	sand and gravel	1,050	110	1,050
	Total	**8,700**	**3,767**	**8,700**
Riverside Wellfield				
RS-2	carbonate	650	340	650
RS-3	carbonate	260	133	260
RS-7	carbonate	900	382	900
RS-8	carbonate	900	597	900
RS-9	carbonate	700	395	700
RS-17	carbonate	700	221	700
RS-18	carbonate	700	NA	700
RS-19	carbonate	700	152	700
RS-22	carbonate	700	318	700
RS-26	carbonate	600	299	600
RS-27	carbonate	800	661	800
RS-28	carbonate	650	NA	650
RS-29	carbonate	600	505	600
RS-A	sand and gravel	1,350	567	1,350
RS-B	sand and gravel	500	180	500
RS-C	sand and gravel	1,200	274	1,200
RS-D	sand and gravel	500	69	500
	Total	**12,410**	**5,093**	**12,410**
White River Wellfield				
WR-3	sand and gravel	1,000	836	1,000
WR-6	sand and gravel	1,000	650	1,000
WR-7	sand and gravel	1,150	864	1,150
WR-8	sand and gravel	901	733	901
WR-9	sand and gravel	1,400	828	1,400
	Total	**5,451**	**3,911**	**5,451**
Total for Wellfields		**26,561 gpm**	**12,771 gpm**	**26,561 gpm**

6. ALTERNATIVE SCENARIOS

6.3.11 Extreme Scenario Modeling

Various existing and future conditions groundwater model simulations were performed to analyze extreme conditions at the request of the project stakeholders. Extreme conditions include much higher hydraulic conductivities for the carbonate aquifer near the Indianapolis Water's wellfields and much higher infiltration rates for a section of the tunnel near the Indianapolis Water's wellfields. Although the available data do not indicate such extreme conditions, these groundwater model simulations provide insight to the impact the tunnel might have on surrounding groundwater levels if such a condition did occur. An example of an extreme "what-if" scenario includes encountering an extremely permeable carbonate aquifer zone near the wellfields during construction. Figure 6.23 shows the area and includes a description of the "what-if" scenarios evaluated.

6.3.11.1 Extreme Scenario A

This scenario was evaluated with the high tunnel infiltration rate previously evaluated along the entire tunnel alignment except for the 1-mile stretch indicated on Figure 6.23. For this 1-mile stretch of tunnel, an infiltration rate of three (3) times the previous high rate was evaluated. The infiltration rates were as follows:

- 6,900 gpm × (7 miles÷8 miles) ≈ 6,040 gpm for seven (7) miles of tunnel
- 6,900 gpm × (1 mile÷8 miles) × 3 ≈ 2,600 gpm for one (1) mile of tunnel near the Riverside wellfield

The model was adjusted to reflect a homogeneous aquifer with a high horizontal hydraulic conductivity of 250 ft/day, and a high vertical hydraulic conductivity of 100 ft/day from ground surface down through the deep carbonate aquifer. These values are up to 100 times greater than the hydraulic conductivities developed for the groundwater model by calibrating to available data.

6. ALTERNATIVE SCENARIOS

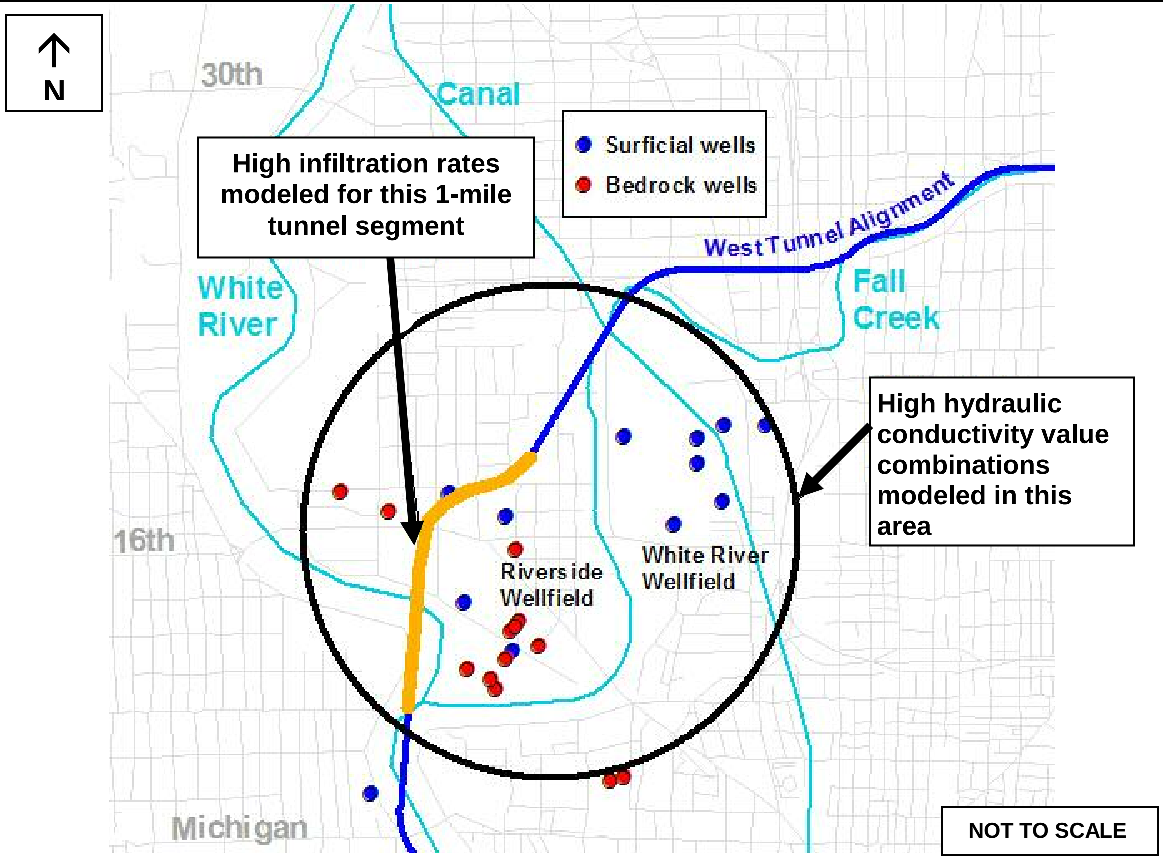

Figure 6.23 Extreme Scenario Modeling

6. ALTERNATIVE SCENARIOS

The major findings from the simulation of this extreme scenario are that: 1) A higher vertical hydraulic conductivity from ground surface down to the depth of the tunnel causes a greater propagation of drawdown for the surficial aquifer; and 2) A high horizontal hydraulic conductivity causes the drawdown created by the tunnel to extend further horizontally on either side of the tunnel alignment. The calibrated model has a vertical hydraulic conductivity of 1.0 ft/day for the carbonate aquifer. Modeling the extreme vertical hydraulic conductivity as previously discussed, the drawdown in the deep carbonate aquifer is greater than the drawdown in the shallow carbonate and surficial aquifer. This concludes that a value of 1.0 ft/day helps to restrict vertical groundwater flow, and reduce the impact of the tunnel on the shallow aquifers.

When modeling the extreme vertical hydraulic conductivity, the aquifers become more hydraulically connected causing the drawdown in the shallow aquifers to be essentially the same as the drawdown in the deep carbonate aquifers. Modeling the extreme horizontal hydraulic conductivity, the drawdown extends further outward from the proposed tunnel centerline. The result indicates that the impact of the tunnel may extend out beneath more of the City and impact more existing wells. However, since the tunnel impacts a greater area with the extreme horizontal hydraulic conductivity, the magnitude of the drawdown near the tunnel alignment decreases.

Figure 6.24 shows an illustration of the resulting drawdown if the aquifer has a high vertical hydraulic conductivity, but a low or moderate horizontal hydraulic conductivity. The drawdown at alluvial well RS-B is significant for this extreme scenario, but it is the only well that is impacted. Figure 6.25 shows that with a high horizontal hydraulic conductivity, the impact on groundwater levels near the tunnel alignment is less than shown in Figure 6.24. However, the drawdown extends further horizontally to impact a greater number of wells. These findings provide an understanding of the effect the tunnel may have on groundwater levels if future information shows the vertical hydraulic conductivity of the carbonate aquifer is higher in some areas due to significant fracturing of the bedrock.

6. ALTERNATIVE SCENARIOS

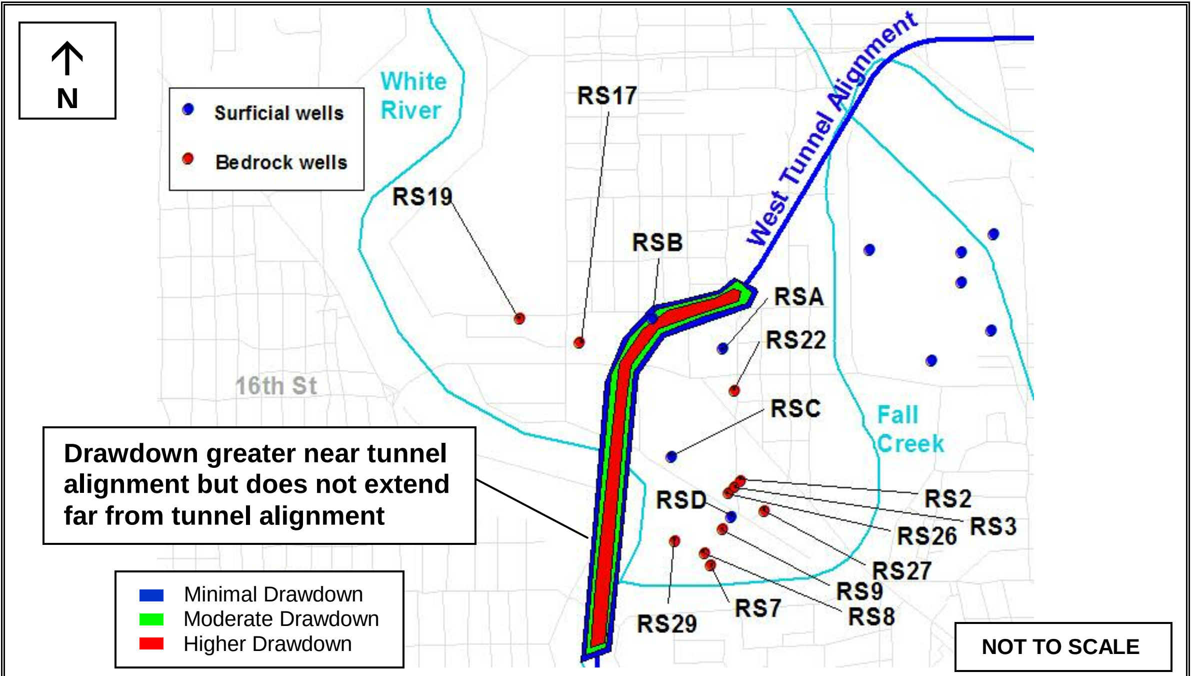

Figure 6.24 Conceptual Illustration of Drawdown in Shallow Aquifers with High Vertical Hydraulic Conductivity and Low to Moderate Horizontal Hydraulic Conductivity

6. ALTERNATIVE SCENARIOS

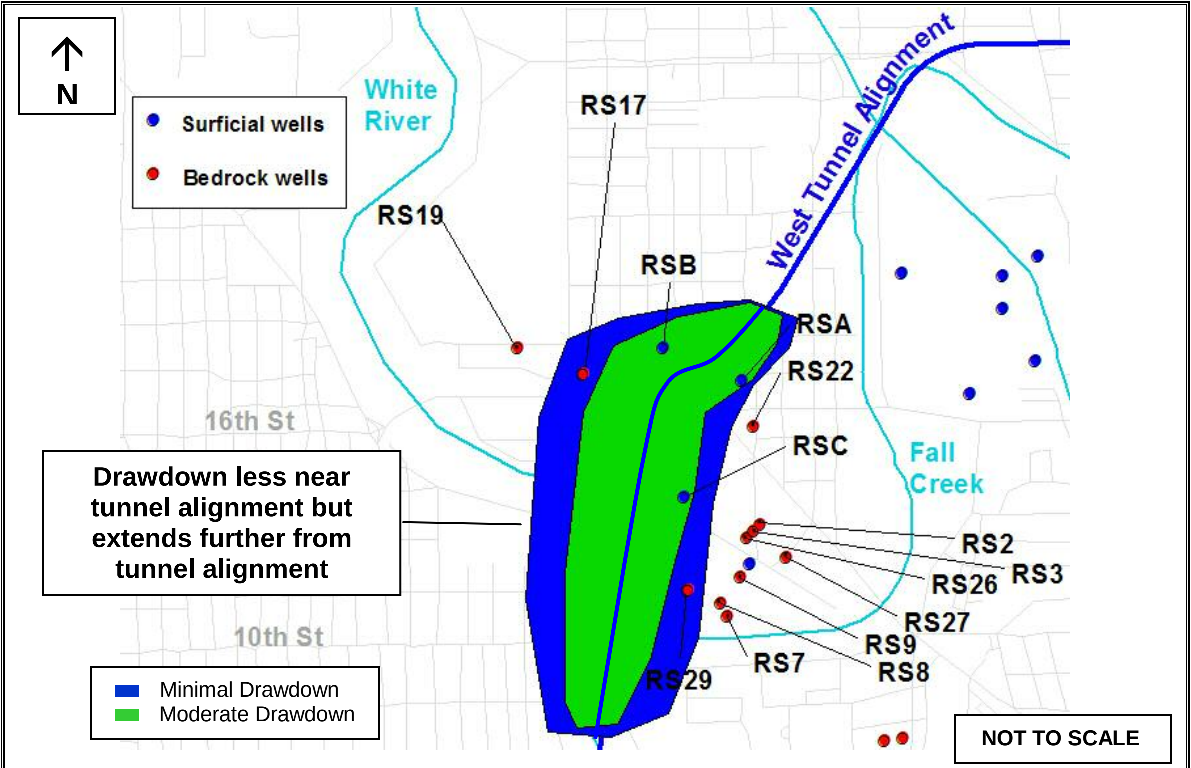

Figure 6.25 Conceptual Illustration of Drawdown in Shallow Aquifers with High Vertical Hydraulic Conductivity and High Horizontal Hydraulic Conductivity

6.3.11.2 Extreme Scenario B

This extreme scenario was simulated by assuming the carbonate aquifer is relatively permeable for its entire thickness around the Riverside wellfield. The tunnel infiltration rate was revised to indicate even higher permeabilities. These conditions are unlikely to occur based on results of the Phase 1A Geotechnical Program and the planned pre-excavation grouting program, but the simulation provides insight to what may happen to groundwater levels in such an extreme case. It was assumed the infiltration rate into the 1-mile stretch of the West tunnel alignment near the Riverside wellfield is approximately 22,400 gpm. This is an extremely high rate assuming a hydraulic conductivity of carbonate is equal to 25 feet/day, as shown on Figure 6.26. This infiltration rate is equivalent to about 32 mgd, which is nearly the same rate as the total capacity of the Riverside, White River, and Fall Creek wellfields combined. At such a high infiltration rate, the concern would not only be for impact to groundwater levels, but also for constructability of the tunnel in such wet conditions. If this situation were to occur, the tunnel would quickly flood and equilibrium would occur within one (1) week.

With these conditions, the model shows that the groundwater levels in the shallow aquifer will drop by as much as 15 feet around some of the Riverside wells (Figure 6.27). Near most wells, the drawdown is between 2 to 10 feet. A more detailed geotechnical investigation and proper pre-excavation grouting program would reduce the possibility of these infiltration rates from occurring, even in the unlikely event that the carbonate has such high permeability along this length of tunnel.

6.3.11.3 Extreme Scenario C

Another groundwater model was developed to show extreme effects of the tunnel if the permeability of the upper carbonate is very high (~100 ft/day) and becomes slightly less permeable with depth, although still permeable in the proposed zone of the tunnel. Figure 6.28 shows the assumed hydraulic conductivities for the various layers in this extreme scenario. The same high infiltration rates used in Extreme

6. ALTERNATIVE SCENARIOS

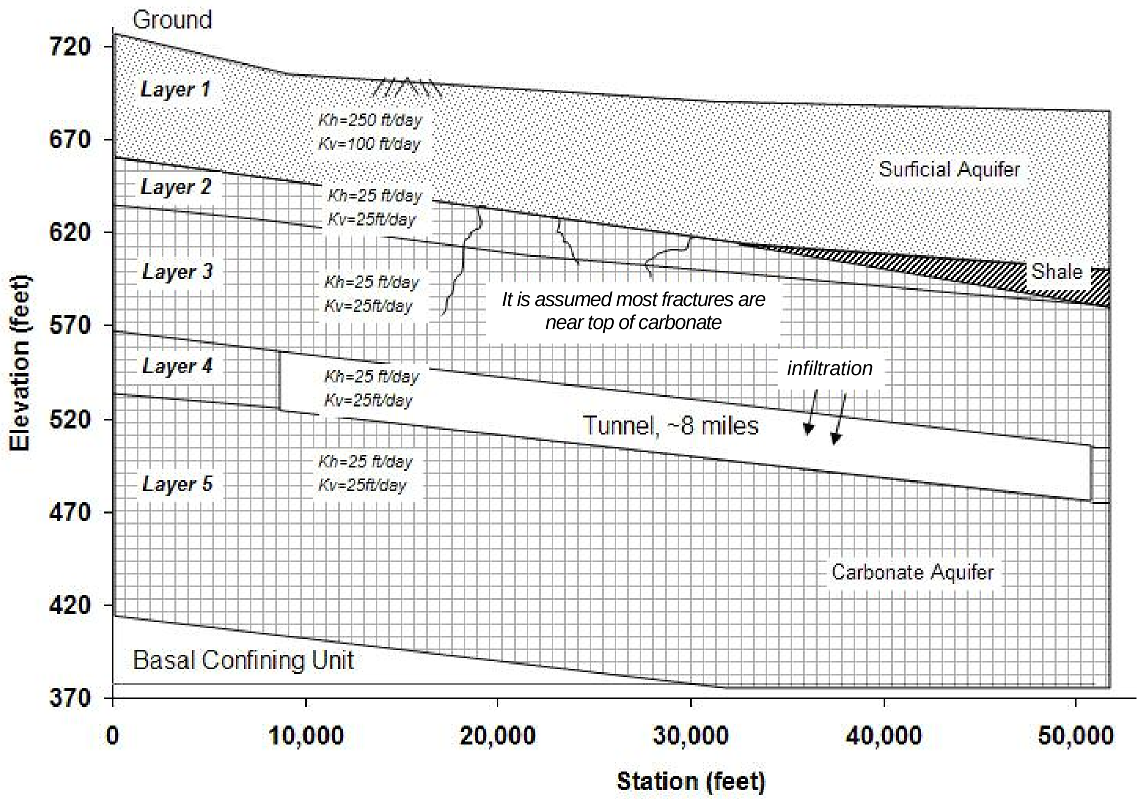

Figure 6.26 Assumed High Hydraulic Conductivity for Carbonate Aquifer for Extreme Scenario B

6. ALTERNATIVE SCENARIOS

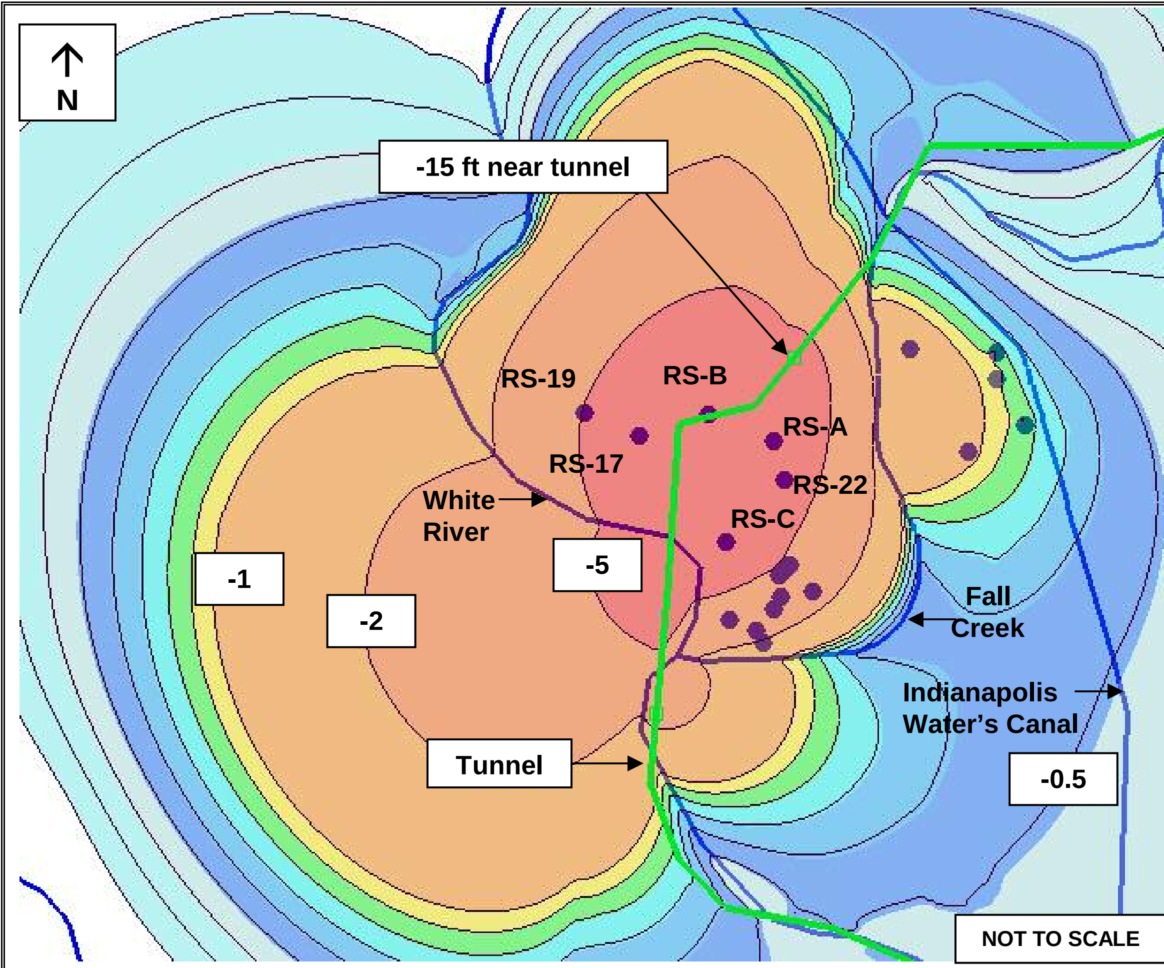

Figure 6.27 Extreme Scenario B – Drawdown of Groundwater Levels for Shallow Aquifers

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6. ALTERNATIVE SCENARIOS

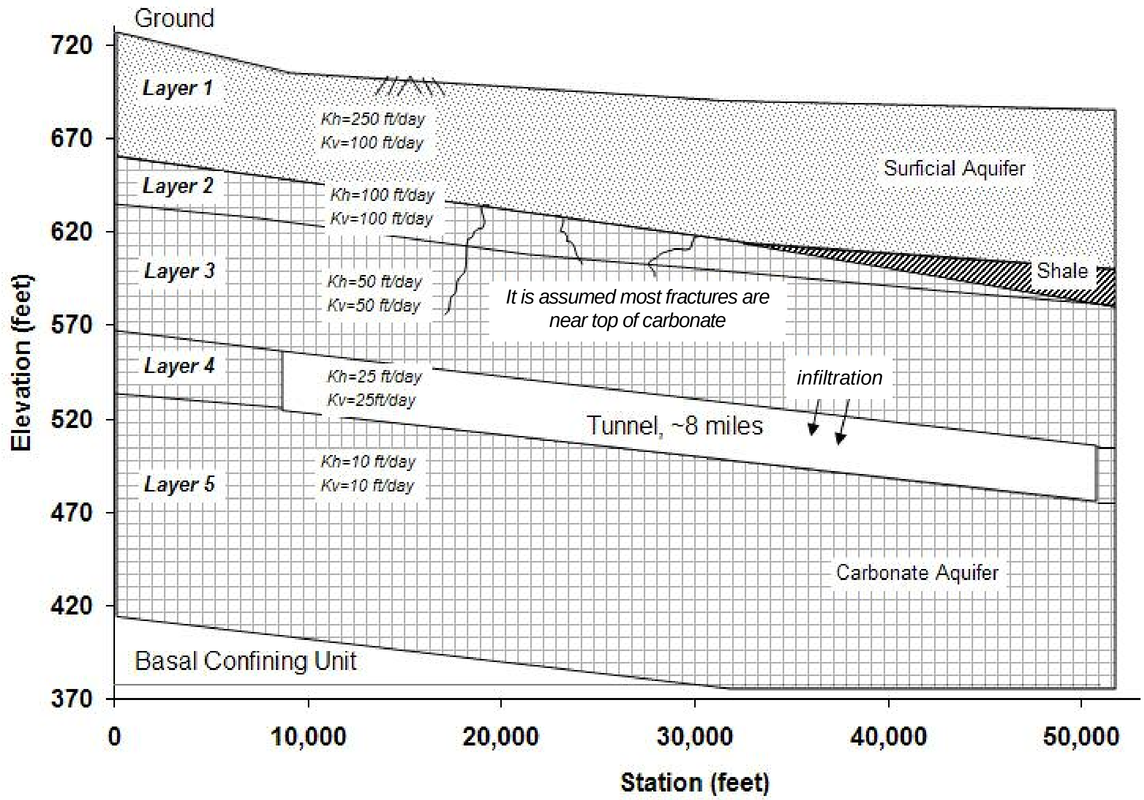

Figure 6.28 Assumed High Hydraulic Conductivity for Carbonate Aquifer for Extreme Scenario C

Scenario B were used for this simulation, which is approximately 22,400 gpm for a 1-mile stretch of tunnel near Riverside Wellfield.

The model results of this extreme scenario are nearly the same as for Extreme Scenario B, which showed a maximum of about 15 feet of drawdown in the shallow aquifer. This indicates that the drawdown of groundwater levels in the shallow aquifers is more dependent on the high tunnel infiltration rate and hydraulic conductivity of the carbonate in the zone of the tunnel, than on the hydraulic conductivity of the shallow carbonate aquifer for the ranges evaluated.

6.3.12 Potential for Exfiltration During Long-Term Tunnel Operation

When the tunnel is placed into service, the total head in the tunnel must exceed the carbonate groundwater head for water to seep out of the tunnel and into the carbonate aquifer. As illustrated by Figure 6.29, the head would need to rise at least 150 feet above the top of the tunnel near monitoring well B-6 to have the potential for seepage to occur. To control this from happening for short periods of time during intense storm events, the design will incorporate ways to control the flow entering and exiting the tunnel, as previously indicated in the Fall Creek/White River Tunnel Evaluation Study and Preliminary Design. Hydraulic modeling of the flows in the tunnel is required to determine the level of design measures that should be incorporated to prevent adverse head pressures from occurring.

6.3.13 Summary of Modeling Results

The results of the alternative scenarios that were modeled are summarized in Table 6.5. The table includes a qualitative assessment of the potential impacts on the surficial alluvial and carbonate aquifers from the alternative scenarios modeling. The Extreme Scenarios are also included in Table 6.5 to show the comparison between each of the alternatives evaluated. As previously indicated and based on the findings from the Phase 1A Geotechnical Investigation, the high infiltration and extreme alternative scenarios are not anticipated during construction or long term operation of the tunnel.

6. ALTERNATIVE SCENARIOS

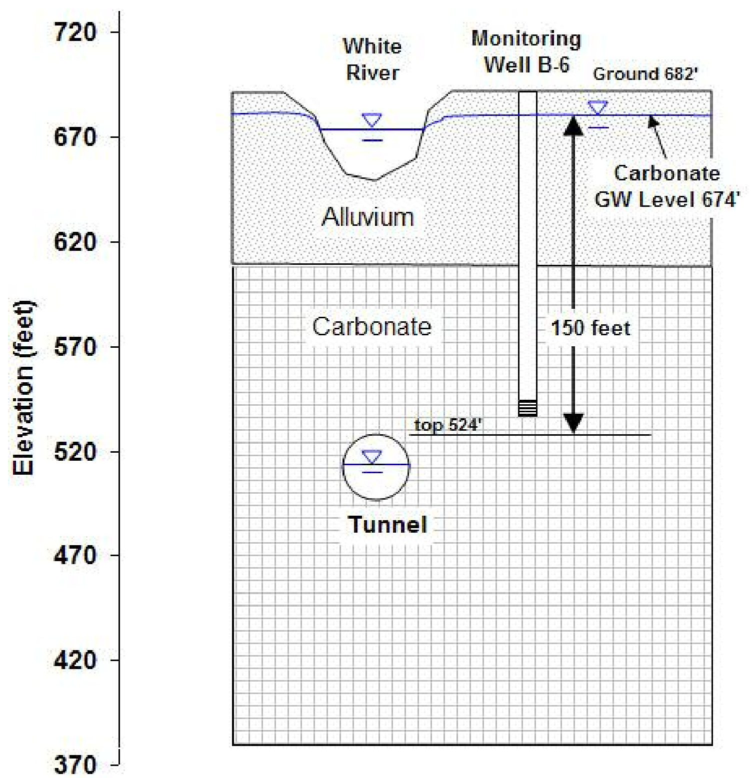

Figure 6.29 Tunnel Elevation Compared to Carbonate Groundwater Level

6. ALTERNATIVE SCENARIOS

Table 6.5
Summary of Alternative Scenarios Modeling Results

Alternative Scenario Identification	Description of Alternative Scenarios	Impact to Surficial Aquifer Levels Near Existing Shallow City Wells	Impact to Shallow Carbonate Aquifer Levels Near Existing Deep City Wells	Notes
1	West alignment, expected infiltration rates during construction	Very low	Very low	
2	Central alignment, expected infiltration rates during construction	Very low	Very low	
3	East alignment, expected infiltration rates during construction	Low	Very low	White River wells WR-3 and WR-8 affected by less than 1 ft of drawdown.
4	West alignment, high infiltration rates during construction	Low	Low	Riverside well RS-B affected by about 1.7 ft; Wells RS-A, RS-C, RS-17, RS-19, RS-22 affected by about 0.7 ft of drawdown.
5	Central Alignment, high infiltration rates during construction	Low	Medium	Indiana University deep well affected by 3.7 ft; other private deep wells affected by 1 to 1.6 ft; WR and RS wells affected by 1 to 1.3 ft.
6	East alignment, high infiltration rates during construction	Medium	Medium	White River wells affected by 2 to 3.1 ft; private alluvial wells affected by 1 to 2.5 ft; Indiana Univ. deep well affected by 3.7 ft; other private deep wells affected by maximum of 2 ft.
7	West alignment, expected infiltration rates during operation	Very low	Very low	
8	Central alignment, expected infiltration rates during operation	Very low	Very low	
9	East alignment, expected infiltration rates during operation	Very low	Very low	
10	West alignment, high infiltration rates during operation	Very low	Very low	
11	Central alignment, high infiltration rates during operation	Very low	Very low	
12	East alignment, high infiltration rates during operation	Very low	Very low	
Extreme "A"	West alignment, extreme infiltration of 2,600 gpm for one mile of tunnel	Medium high	Medium High	Nearly 100 times the calibrated model's horizontal and vertical hydraulic conductivities near Riverside and White River Wellfields.
Extreme "B"	West alignment, very extreme infiltration of 22,400 gpm for one mile of tunnel	High	High	This modeled scenario is highly unlikely, and provided as a worst-case scenario. Data from the Phase 1A Geotechnical Investigation does not indicate conditions to validate the likelihood of this extreme scenario.
Extreme "C"	West alignment, very extreme infiltration of 22,400 gpm for one mile of tunnel and highly permeable shallow aquifer	High	High	This modeled scenario is highly unlikely, and provided as a worst-case scenario. Data from the Phase 1A Geotechnical Investigation does not indicate conditions to validate the likelihood of this extreme scenario.

* Legend:
"Very low" = Less than 1 foot drawdown in aquifer layers that wells extract groundwater.
"Low" = Between 1 and 2 feet of drawdown in aquifer layers that wells extract groundwater.
"Medium" = Between 2 and 5 feet of drawdown in aquifer layers that wells extract groundwater
"High" = Greater than 10 feet of drawdown in aquifer layers that wells extract groundwater.
RS = Riverside Well
WR = White River Well

6. ALTERNATIVE SCENARIOS